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SMORN-III BENCHMARK TEST ON REACTOR NOISE ANALYSIS METHODS

February 1984

Edited
by
Yoshikuni SHINOHARA and Jitsuya HIROTA

日本原子力研究所
Japan Atomic Energy Research Institute

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(Received January 25, 1984)

A computational benchmark test was performed in conjunction with the Third Specialists Meeting on Reactor Noise (SMORN-III) which was held in Tokyo, Japan in October 1981. This report summarizes the results of the test as well as the works made for preparation of the test.

Keywords: Reactor Noise, Noise Analysis, Benchmark Test, SMORN-III

[+] Special Staff of JAERI

炉雑音解析手法に関するSMORN－IIIベンチマークテスト

日本原子力研究所東海研究所原子炉工学部
（編）篠原　慶邦・弘田　実弥[+]

（1984年1月25日受理）

1981年10月に東京で開催された第三回炉雑音専門家会合と関連して，数値計算のベンチマークテストが行われた。本報告書はテストの準備作業並びにテストの結果を要約したものである。

[+] 特研研究員

CONTENTS

1. INTRODUCTION

In conjunction with the Third Specialists Meeting on Reactor Noise (SMORN-III), held in Tokyo, Japan from 26 to 30 October 1981, a benchmark test on reactor noise analysis methods was made. It was the first trial in the field of reactor noise analysis and was performed successfully with participation of 23 groups of applicants.

The test was designed as a computational rather than a physical benchmark test because it was considered to be better to make a computational test first and then proceed to a physical one only if the former was performed successfully.

The detailed information about the benchmark test results has been shown so far only to those who attended the informal meeting of the contributors to the test which was held in the evening of 27 October 1981, although a brief summary of the results was presented at the final session of SMORN-III.

At the informal meeting, it was agreed to publish the results of the benchmark test together with the related information in order that they may be available to those who are interested in the benchmark test performed. It was also agreed that the test data may be utilized without any restriction for further research and that it would be worthwhile to perform a physical benchmark test in the near future using the same source data used for Tthe SMORN-III benchmark test.

Meanwhile, a physical benchmark test has recently been proposed to be conducted in conjunction with SMORN-IV which will be held in France in October 1984. The aim of this report is to summarize the computational results of SMORN-III benchmark test as well as the preparational works by compiling the materials of interest and to make it available as a reference material for the physical benchmark test for SMORN-IV.

2. COMMITTEE ACTIVITIES

At the 21st Meeting of the NEACRP held in 1978, it was proposed to hold the Third Specialists Meeting on Reactor Noise (SMORN-III) in 1981 in Japan. In order to make necessary technical preparations, the Japanese Preparatory for SMORN-III was organized in April 1979 as one of the subcommittees of the Committee on Reactor Physics of JAERI. The

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2. COMMITTEE ACTIVITIES

At the 21st Meeting of the NEACRP held in 1978, it was proposed to hold the Third Specialists Meeting on Reactor Noise (SMORN-III) in 1981 in Japan. In order to make necessary technical preparations, the Japanese Preparatory for SMORN-III was organized in April 1979 as one of the subcommittees of the Committee on Reactor Physics of JAERI. The member of the Preparatory Committee consisted of eleven representatives from universities, nuclear industries, Power Reactor and Nuclear Fuel Development Corporation (PNC) and JAERI. The main role of this Committee was to discuss on the topics to be proposed for SMORN-III and to prepare necessary technical documents.

As one of the major topics to be discussed at SMORN-III, it was proposed to make a benchmark test on reactor noise analysis. The objective of the test was to reveal computational problems associated with reactor noise analysis and to obtain useful information for providing some basis for standardization of data presentation.

During the first one and a half year the Committee held ten meetings and devoted itself mostly for discussions on the benchmark test problems as well as the major topics to be proposed for SMORN-III. It was reorganized in November 1980 into the Technical Program Committee under the Japanese Organizing Committee for SMORN-III.

The preparation of the benchmark test was made also in collaboration with the International Organizing Committee for SMORN-III as well as NEACRP. It was through these collaborations that two kinds of actual reactor noise data, the one from the Netherlands and the other from France, were supplied for the benchmark test. This type of international collaboration was very important because it was one of the major topics proposed for SMORN-III and also because it made the test very fruitful.

The role of the Technical Program Committee was to promote technical preparation for SMORN-III, especially for the benchmark test, while the main role of the Japanese Organizing Committee was to coordinate the cooperation of the interested organizations in Japan. The Technical Program Committee held eight meetings until it terminated its role in November 1981 shortly after SMORN-III.

As the result of the discussions made at the Technical Program Committee meetings, it was decided that the benchmark test for SMORN-III should be computational rather than physical one because it was considered better not to be too ambitious as the the first trial in the field of reactor noise analysis. This decision led the benchmark test to a success because even from the computational test many important things could be learnt through the preparational work and the test itself.

The member of the International Organizing Committee and the Technical Program Committee as well as those who contributed for the preparation of the benchmark test data are listed in Table I. The list of the contributors to the benchmark test analysis is given in Table II.

3. PREPARATION OF TEST DATA

3.1 Source Data

a. Artificial BWR-like noise data

In August 1980, the work for generating BWR-like noise data was made at Reactor Control Laboratory of JAERI by Dr. Yamada and graduate students of Osaka University in collaboration with JAERI staffs using the hybrid computer installed at the Laboratory.

A theoretical model of BWR-like reactor noise, developed by Dr. Morishima based on a simplified model of an experimental BWR (JPDR-II) was simulated on the analog part of the hybrid computer. A seven channel analog data recorder was used as a multichannel noise generator which provides seven statistcally independent white noise signals.

Eight variables in this BWR model as well as two input noise signals were recorded. The recorded time length was about six hours in real time scale. In order to shorten the actual time required for data recording, the data recorder was run fast and the time scale factor for analog simulation was so chosen that the recorded signals can be reproduced in real time scale at a playback speed of 1-7/8 ips.

b. PWR noise data

According to the proposal made by Dr. Dragt of ECN, The Netherlands at the meeting of the International Organizing Committee held in Paris on 5 May 1980, an analog magnetic data tape containing the reactor noise data taken at Borssele reactor was sent to JAERI in September 1980 from Dr. Turkcan of ECN. The tape included twelve neutron and two pressure signals.

c. FBR noise data

According to the recommendation made at the 23rd Meeting of NEACRP held in Idaho, USA in September 1980 to add the Phenix reactor noise data to the benchmark test, a data tape was sent to JAERI from Dr. Gourdon of CEN-Cadarach, France in December 1980. The tape contained two preparation of the benchmark test data are listed in Table I. The list of the contributors to the benchmark test analysis is given in Table II.

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3.2 Compilation, Copying and Check of the Test Data

The applicants to the benchamark test had been requested to write in the Application Form about the type of data recorders available in their laboratory for reproducing the test data. Since it turned out that the analog data recorder of IRIG standard with 14 tracks were available to most of the applicants, it was decided to use an analog magnetic tape of 1 inch wide and 3600 feet long for recording of the test data and to take roughly equal length of data from each souce data. Although only two signals from each of three source data were to be used for the test, all other signals that had been recorded simultaneously on the original data tape were also copied on the tape to be distributed to the applicants because it was considered that these data might be used in the near future for a possible physical benchmark test.

The condition of recording was so chosen that the recorded signals can be reproduced in real time scale if the tape is played back at a speed of 1-7/8 ips in Intermediate Band of IRIG standard. The time length for each of three sets of test data including the corresponding calibration signals was determined, therefore, to be about 120 min. A master tape on which the compiled data were recorded was thus made by making necessary conversions for compilation of three source data since the tape speed and the frequency band used in the original recordings was not the same for these source data. A detailed information about the test data is given in Appendix A.

The test data tapes distributed to the applicants were copied from the master tape using the same data recorders in order to keep the same recording condition for all copied data, taking into consideration that low level recording noise which are dependent to some extent on the data recorders used might be added in the process of copying. Low level noises might have added also in the process of compilation of the test data. In order to save the time required for copying the data from the master tape, the tapes were run at a speed of 30 ips. The total number of the tapes thus copied was 28.

Every copied tape was checked by reproducing all the recorded signals and monitoring the power spectral density functions for specified portions of the selected signals to be used for the benchmark test. Each tape was given its identification number in order to know if any additional noise might appear in the results obtained by the applicants due to possible noise added in the process of signal reproduction using different data recorders. The test data have been sent from JAERI to the applicants by the end of March 1981.

Certain portions of the analog test data were digitized and recorded on a digital magnetic tape and its copies were sent to four applicants. A copy of this tape was also sent to NEA Data Bank in March 1981. The detailed information about the digitized version of the test data is given in Appendix B.

4. TEST RESULTS

There were 23 groups of applicants from 9 countries who submitted their results of analysis. This number was about twice more than that was expected by the Preparatory Committee.

Although the time available for reviewing the test results was very short before SMORN-III meeting, a summary report was prepared by Prof. Suda of Osaka University and was presented at the informal meeting of the contributors to the benchmark test which was held in the evening of 27th and also at the final session of SMORN-III on 30th October 1981. In Appendix C is attached the summary report.

The following remarks should be made in addition to the above mentioned summary report.

At the informal meeting of the contributors, Dr. Gourdon indicated that there were some differences between the power spectral density functions which were obtained for the original data and those for the copied data distributed by JAERI in high frequency region of the spectra. These differences seem due to the recording noise which were added in the process of data compilation and copying.

In Appendix D are shown the graphs which are obtained by superimposing the results submitted by different groups of contributors.

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In Appendix D are shown the graphs which are obtained by superimposing the results submitted by different groups of contributors.

5. CONCLUSION

Although the SMORN-III benchmark test was limited to computational one, it was successful in showing a variety of different practices in reactor noise analysis performed by different groups of contributors and the problems which must be considered carefully in practical application of analysis methods. From this point of view, it can be concluded that the SMORN-III benchmark test has fulfilled its role as the first step of the benchmark test in the field of reactor noise analysis and that it is now meaningful to proceed to a physical benchmark test as the second step.

TABLE I. Members of Committees and Collaborators

A. NEA International Organizing Committee for SMORN-III

Hirota, J. (Chairman)	JAERI	Japan
Bastl, W.	GRS-Garching	FRG
Booth, R. S.	ORNL	USA
Bouchard, J.	CEN-Cadarache	France
Cox, R. J.	UKAEA-Winfrith	UK
Dragt, J. B.	ECN-Petten	The Netherlands
Edelmann, M.	KFZ-Karlsruhe	FRG
Kuroda, Y.	Tokai University	Japan
Pacilio, N.	CSN-Casaccia	Italy
Johnson, D. M. (Secretary)	NEA-Data Bank	OECD

B. Japanese Organizing Committee for SMORN-III

Ishikawa, H. (Chairman)	JAERI
Asaoka, T.	JAERI
Endou, Y.	CRIEPI
Fuketa, T.	JAERI
Hirota, J	JAERI
Katsuragi, S.	JAERI
Inoue, T.	JAERI
Kokubu, I.	JAIF
Kuroda, Y.	Tokai Univ.
Miida, J.	JAERI
Nishihara, H.	Kyoto Univ.
Nomura, S.	JAERI
Sato, K.	JAERI
Wakayama, N.	JAERI
Kikuchi, S. (Secretary)	JAERI
Shinohara, Y. (Secretary)	JAERI
Yoshizawa, K. (Secretary)	JAERI

TABLE I. Members of Committees and Collaborators (continued)

C. Technical Program Committee

Hirota, J. (Chairman)	JAERI
Kuroda, Y. (Vice-Chairman)	Tokai Univ.
Fukunishi, K.	Hitachi Ltd.
Idesawa, M.	TEPCO
Izumi, I.	MAPI
Kato, Y.	KEPCO
Matsuno, Y.	PNC
Nishihara, H.	Kyoto Univ.
Saito, K.	Tsukuba Univ.
Shinohara, Y.	JAERI
Suda, N.	Osaka Univ.
Tsunoda, T.	NAIG
Wakabayashi, J.	Kyoto Univ.

D. Collaborators for Preparation of Test Data and Problems

Gourdon, J.	CEN-Cadarache	France
Turkcan, E.	ECN-Petten	The Netherlands
Kishida, K.	Gifu Univ.	Japan
Morishima, N.	Kyoto Univ.	Japan
Yamada, S.	Osaka Univ.	Japan
Fujii, Y.	JAERI	Japan
Hayashi, K.	JAERI	Japan
Watanabe, K.	JAERI	Japan

TABLE II. List of Groups of Contributors

No.	Country	Name	Organization	Data	Method
1.	France	Bernard, P. Cloue, J. Messainguiral, C.	CEN-Cadarache	A-15	FFT
2.	France	Leguillou, G. Gourdon, J.	CEN-Cadarache	A-14	FFT
3.	F.R.G.	Bauernfeind, V. Rosler, H. Sadtler, E. Wach, D.	GRS-Garching	A-8	FFT
4.	F.R.G.	Massier, H.	KFZ-Karlsruhe	A-7	FFT
5.	Hungary	Valko, J.	HAS/CRIS-Budapest	A-3	FFT
6.	Italy	Federico, A. Galli, C.	CNEN-Roma	A-10	FFT
7.	Italy	Giovannini, R. Marseguerra, M. Martinelli, T. Motta, M. Taglienti, S.°	CNEN-Bologna CNEN-Roma°	A-10	FFT
8.	Japan	Hayashi, K.	JAERI	A-1	B-T FFT AR MEM
9.	Japan	Morishima, N.	Kyoto Univ.	A-2	FFT
10.	Japan	Kimura, Y. Nishihara, H.	Kyoto Univ.	Copy of A-2	FFT
11.	Japan	Yamada, S. Kishida, K.° Nishimura, T. Bekki, K.	Osaka Univ. Gifu Univ.°	Copy of A-2	FFT
12.	Japan	Kuroda, Y.	Tokai Univ.	D-2	AR ARMA
13.	Japan	Saito, K. Konno, H. Fujita, H.	Univ. of Tsukuba	D-4	B-T
14.	Japan	Fujita, Y. Ozaki, H.	MAPI	Copy of Original-	FFT

Table II. List of Groups of Contributors (continued)

No.	Country	Name	Organization	Data	Method
15.	Japan	Tamaoki, T.	NAIG	Copy of Original	FFT
16.	Netherlands	Kleiss, E.B.J.	IRI-Delft	A-6	FFT
17.	Netherlands	Turkcan, E.	ECN-Petten	A-9	FFT
18.	Netherlands	Van der Veer, J.	NV-KEMA	A-4	FFT
19.	Sweden	Akerhielm, F.	Studsvik	A-13	FFT
20.	Sweden	Bergdahl, B.-G.	Studsvik	A-13	AR
21.	U.K.	Rowley, H.	UKAEA-Risley	A-17	FFT
22.	U.S.A.	Kryter, R.C.	ORNL	A-5	FFT
23.	U.S.A.	Ouyang, M.S. Wu, S.M.	Univ. of Wisconsin-Madison	A-12	ARMA

Notes: Data: A - Analog data tape
D - Digital data tape
Number - Identification number (e.g. A-15)

B-T: Blackman-Tukey Method
FFT: Fast Fourier Transform Method
AR: Autoregressive Method
ARMA: Autoregressive Moving Average Method
MEM: Maximum Entropy Method

APPENDIX A

Information Sheets Distributed to the Applicants

This information sheet on SMORN-III benchmark test was distributed to the applicants about six months before the SMORN-III meeting with the magnetic tape containing the test data.

Reactor Noise Analysis

Benchmark Test for SMORN-III

A. General Information

A.1 Objective

The objective of this benchmark test is to make comparison among the results obtained for identical test data by different noise analysis methods and thereby to identify data processing problems to be solved before a reliable data base of processed reactor noise can be established. The test is therefore aimed at computational rather than physical benchmark.

The reason for limiting the test to the computational benchmark are: (1) only one session may probably be shared for the benchmark test discussion in SMORN-III; (2) much more time is necessary for preparing meaningful physical benchmark test problems and for the discussion, and (3) a computational benchmark test should precede a physical benchmark test which may be a topic of a future meeting.

The test data distributed to the applicant should be analysed, according to the task specification described in C, using the methods which the applicant considers to be most appropriate. The results will be compared for different methods and conditions of analysis, e.g. analog vs. digital; time domain vs. frequency domain; sampling interval; pre-processing modes, etc.

A.2 Test Data

Each applicant or group of applicants will receive an analog data tape (1 inch wide, 14 channels, 3600 feet long) in which are copied three types of noise data consisting of artificial noise from Japan, Borssele reactor noise from the Netherlands and Phenix reactor noise from France. Although the tape contains various data, only the data recorded in Channels 1 and 2 of the artificial and Borssele data, and Channels 1 and 5 of the Phenix data, will be used for the present test. As it is intended to make a computational benchmark test, the data have been chosen from the numerical but not from the reactor physics point of view.

The purpose of including data not used in the present test is to convey to the applicants some parts of the original source data which may be used in a future physical benchmark test if it is considered to be useful.

The original source data is described in detail in Appendix 1, but note that there are some differences between the actual ordering of the channels on the tapes distributed and the description in this document. For the Borssele data, channels 1 (IN 12) and 2 (LOG) on the tape are to be analysed and correspond to channels 9 and 10 respectively in Table 2.1 of Appendix 1. Only the second recording of the Phenix data has been included on the tapes and channels 1 (TATA 2018) and 5 (Z1MRS1) on the tapes are to be analysed, corresponding to track numbers 3 and 2 respectively in Table 3.2 of Appendix 1.

A.3 Schedule and Mailing Address

The source noise data for the tests and the reporting format will be sent to the applicants in April 1981. The applicants are requested to send their results to:

Dr. Jitsuya HIROTA
Japan Atomic Energy Research Institute
Tokai Research Establishment
Tokai-mura, Naka-gun
Ibaraki-ken 319-11
JAPAN

to arrive in Japan by the end of August 1981 at the latest, in order to make it possible for a reporter to summarise the results at SMORN-III.

A.4 Review Paper

A review paper will be presented on the results of the benchmark test. The attendance to this presentation is not restricted to the contributors to the benchmark test, but is open to all the SMORN-III participants.

In this review, general comparisons of the analysed results are made and, if there is some remarkable difference, its possible origin will be discussed. As a rule, the contributor of any particular result will not be identified.

During SMORN-III, it is planned to have an informal meeting of the contributors to the benchmark test. The objective is to elaborate the comparisons and prepare a detailed report, apart from the SMORN-III proceedings, on the test results.

B. Description of the Data Tape

The data tape contains the following signals in the order as shown in Figure 1.

A: Checking signals at the beginning of data copying.
B: Artificial noise data with the original calibration signals.
C: Borssele reactor noise data with the original calibration signals.
D: Phenix reactor noise data with the original calibration signals.
E: Checking signals at the end of data copying.

The contents of each noise data are as follows: (See Appendix 1 for further information).

1. Artificial noise

Channel No. 1: neutron density
2: vessel pressure with additive noise
3: inlet water velocity
4: location of boiling boundary
5: heat flux per unit length
6: inlet water enthalpy
7: recirculation flow
8: void volume in core
9: noise source f_2
10: noise source f_{10}

2. Borssele reactor noise data

Channel No.	1:	in-core detector signal-	(IN 12)
	2:	ex-core detector signal	(LOG)
	3:	in-core	(IN 15)
	4:	ex-core	(LIN)
	5:	in-core	(IN 14)
	6:	ex-core	(D 62)
	7:	in-core	(IN 13)
	8:	ex-core	(D 72)
	9:	in-core	(IN 16)
	10:	ex-core	(D 82)
	11:	in-core	(IN 11)
	12:	ex-core	(D 52))
	13:	pressure	(YA01 P001)
	14:	pressure	(YA02 P001)

3. Phenix reactor noise data

Channel No.	1:	subassembly outlet temperature	(TATA 2018)
	2:	subassembly outlet temperature	(TATA 2024)
	3:	ex-core ion chamber	(Z1MR41)
	4:	subassembly outlet temperature	(TATA 2119)
	5:	ex-core ion chamber	(Z1MR51)
	6:	pump inlet temperature	(P3MT25)
	7:	primary pump flowrate	(P1MQ02)
	8:	secondary pump flowrate	(S1MQ01)
	9:	IHX primary inlet temperature	(P1MT01)
	10:	IHX secondary inlet temperature	(S1MT01)

The recorded data can be reproduced in real-time when the tape is played back at 1-7/8 ips in Intermediate Band (IRIG band).

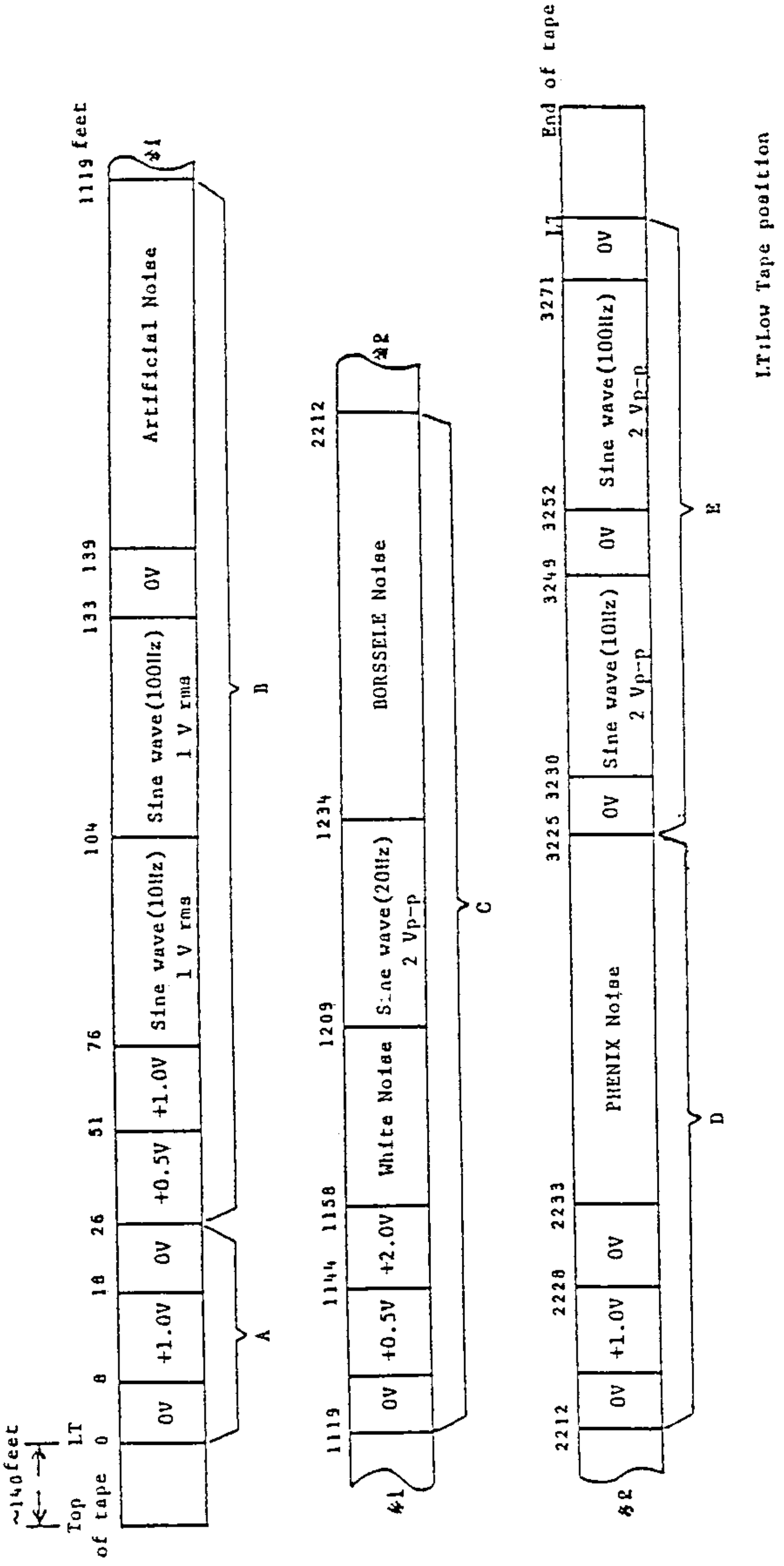


Fig. 1: Order of signal recording in the data tape

C. Tasks and Related Information

C.1 Tasks

The test data recorded in the magnetic tape consist of three sets of noise signals. They are the artificial noise synthesized using a hybrid computer and the real reactor noise from two operating power reactors, Borssele reactor (PWR) and Phenix (FBR). For each set of noise data, you are requested to analyse the noise data recorded in channels 1 and 2 of the artificial and Borssele data, and channels 1 and 5 of the Phenix data, and report the standard deviations and the following functions in graphical form:

1) Normalized Auto-Correlation Functions: $\overline{C}_{11}(T)$, $\overline{C}_{22}(T)$
2) Normalized Cross-Correlation Function: $\overline{C}_{12}(T)$
3) Auto Power Spectral Density Functions: $P_{11}(f)$, $P_{22}(f)$
4) Cross Power Spectral Density Function: $P_{12}(f)$
5) Coherence Function: $Coh_{12}^2(f)$

Note: For suffix 2 read suffix 5 in the case of the Phenix data

C. 2. Definitions of the Functions

For random variables $x_i(t)$, i.e. the noise signals recorded in channel i (i=1 or 2), the functions in the tasks are defined as follows:

1) Normalized Auto-Correlation Function: $\overline{C}_{ii}(T)$

$$\overline{C}_{ii}(T) = C_{ii}(T) / C_{ii}(0)$$

where $C_{ii}(T) = E[x_i(t)x_i(t+T)] - \{E[x_i(t)]\}^2$

2) Normalized Cross-Correlation Function: $\overline{C}_{12}(T)$

$$\overline{C}_{12}(T) = C_{12}(T) / \sqrt{C_{11}(0)\ C_{22}(0)}$$

where $C_{12}(T) = E[x_1(t)x_2(t+T)] - E[x_1(t)]E[x_2(t)]$

3) Auto Power Spectral Density Function: $P_{ii}(f)$

$$P_{ii}(f) = \int_{-\infty}^{\infty} C_{ii}(T)\exp(-j2\pi f)dT$$

4) Cross Power Spectral Density Function: $P_{12}(f)$

$$|P_{12}(f)| = \sqrt{\{Re[P_{12}(f)]\}^2 + \{Im[P_{12}(f)]\}^2} \quad : \text{(magnitude)}$$

$$\underline{/P_{12}(f)} = \tan^{-1}\{Im[P_{12}(f)] / Re[P_{12}(f)]\} \quad : \text{(phase)}$$

$$-\pi \leq P_{12}(f) \leq +\pi \quad \text{(in the sense of ATAN2 in FORTRAN)}$$

where $P_{12}(f) = \int_{-\infty}^{\infty} C_{12}(T)\exp(-j2\pi f)dT$

5) Coherence Function: $Coh_{12}^2(f)$

$$Coh_{12}^2(f) = |P_{12}(f)|^2 / P_{11}(f)P_{22}(f)$$

C.3 Format for graphical data presentation*

1. Each graphical data should be presented in the format specified. Figure must be drawn in black ink with clear lines and sizeable letters. It is difficult to reproduce from "dye-line" prints or from prints with weak lines. Each figure must be labelled in the margin with at least the figure title and the author's name.

2. Power spectral density functions should be presented on a logarithmic scale of 6 (vertical) x 4 (horizontal) decades. The scale of one decade should be equal to 4 cm. Units should be Hz^{-1} for the vertical axis and Hz for the horizontal axis. The frequency range should be from 5×10^{-3} Hz to 5×10 Hz.

   In addition, to facilitate the detailed comparison, power spectral density functions should be presented on another logarithmic scale of 4 (vertical) x 1 (horizontal) decade, with the frequency range from 0.2 to 2.0 Hz for the artificial noise, from 2.0 to 20 Hz for the Borssele noise and from 0.1 to 1.0 Hz for the Phenix noise, respectively. In this case, 6 cm. should correspond to one decade for the vertical axis and 16 cm. to one decade for the horizontal axis.

3. The phase of the cross power spectral density function and the coherence function should be presented on linear scale for the vertical axes, while the horizontal axes should be the same as in the case of power spectral density functions. 10 cm. should correspond to (0 to 1) for the coherence and ($-\pi$ to $+\pi$ radian) for the phase, respectively.

4. Normalised correlation functions should be presented on linear scale both for vertical and horizontal axes. 10 cm. should correspond to (0 to 1) for the vertical and (0 to 10 sec) for the horizontal axis, respectively. If the correlation function does not decay sufficiently at the lag time of 10 sec., another graph should be added taking 10 cm. for 100 sec.

5. Location of the data points computer should be indicated in your graphs or in the form of a list.

* Note: If the specified format size is not convenient for you, you may choose another graph size keeping the ratio of vertical to horizontal scales the same as that for the case above and not changing the graph size significantly.

C.4 Questionnaire

The applicants to the tests are requested to fill in the questionnaire in D. This information will be useful for making comparisons among the test results reported.

D. Questionnaire

Name: ______________________________

Organization: ______________________________

Business Address: ______________________________

____

1. From where did you obtain the test data?

   (a) ☐ JAERI
   (b) ☐ NEA Data Bank
   (c) ☐ Others

   If your answer is (a), please write the identification number of the tape.

   ____

   If the answer is (c), please specify the source of the data and the means of acquisition.

   ____
   ____
   ____

2. If the test data analyzed is in analog form, please write the model and its main specifications of the data recorder used for playing back the tape.

   ____
   ____
   ____
   ____

3. If the source noise data analyzed is in analog form, please answer how you processed the data.

   (a) ☐ processed in analog form throughout the analysis.
   (b) ☐ processed in digital form except for analog-digital conversion of the source noise data at the outset of the analysis.
   (c) ☐ combination of analog and digital processings.

   If your answer is (b) or (c), please write the number of bits for quantization of the analog noise data.

   ____

4. The system used for analyzing the data is
   (a) [ ] commercially available.
   (b) [ ] specially organized by yourself.

   If your answer is (a), please write the model of the analyzer.

   ____

5. Please draw the block diagram of your data analyzing system.

6. Does your analysis include pre-processing of the source noise data?
   (a) ☐ Yes
   (b) ☐ No

   If your answer is "Yes", please specify the type of pre-processing.

7. What type of method did you use for analyzing the data?
   (a) ☐ Blackman-Tukey method
   (b) ☐ Fast or Direct Fourier Transform method
   (c) ☐ Auto-regressive (moving average) model fitting
   (d) ☐ Maximum entropy method
   (e) ☐ Others

   Please state the specific feature of your algorithm, the order of the AR model, the criterion for determination of the order of the model, etc.

8. Please write your analyzing conditions in the form of the table attached with this questionnaire. If the space is not enough, please use separate sheets for additional information.

   Directions for filling the table.
   (a) Since the frequency resolution depends upon the analyzing method, please specify the definition of the frequency resolution which you used.
   (b) If the data analyzed is in analog form, the data length used for an analysis should be expressed by the time spent for retrieving the analog data required for an analysis at the playing back speed of 1-7/8 ips.
   (c) Please write in columns (7) and (8) only identification numbers of your description of the filter (F) and window (W) such as F1, F2, F3, or W1, W2, W3, etc., and it is requested to use separate sheets for describing full information concerning filters and windows such as transfer functions of filters, correlation functions of windows or graphical presentations of their characteristics.

9. Numerical data obtained by the analysis.

   1) Standard deviation of the noise recorded in Channel 1

      Artificial noise:
      Borssele noise :
      Phenix noise :

   2) Standard deviation of the noise recorded in Channel 2

      Artificial noise:
      Borssele noise :
      Phenix noise :

10. Error evaluation (optional).

    Please comment on the error evaluation of your results, and superimpose the error-bar on your graphical data if possible.

11. Please write other findings if any.

12. Please write your comments and suggestions concerning the benchmark test.

The name of the variable: ____________________

(1) Frequency range [Hz]	(2) Sampling rate [1/sec]	(3) Number of averaging	(4) Data length used for an analysis [sec]	(5) Total length of analyzed data [sec]	(6) Frequency resolution [Hz]	(7) Type of filter analog or digital	(8) Type of window	(9) play back speed of the tape [ips]	(10) Maximum correlation lag [sec]
						analog digital			
						analog digital			
						analog digital			
						analog digital			
						analog digital			
Total frequency range analyzed is from Hz to Hz.									

APPENDIX 1

Description of the recorded noise data

1. Artificial Noise data

A simplified boiling water reactor model of JPDR-II was built on a hybrid computer. Independent artificial noise signals from noise generators are fed to the model at a few points. Fig.1.1 shows the block diagram of the linearized model of JPDR-II, and the transfer functions with arbitrary parameters are listed in Table 1.1.

Noise signals recorded are adjusted so that they have the same order of standard deviations, and coherence functions approach to unity at higher frequency due to the model without detection noise.

The recorded noise signals of the selected system variables are as follows:

Channel 1 : x_1 Neutron Density
2 : x_2 Vessel Pressure
3 : x_3 Void Volume in Core
4 : x_4 Heat Flux per Unit Length
5 : x_5 Inlet Water Velocity
6 : x_6 Location of Boiling Boundary
7 : x_7 Inlet Water Enthalpy
8 : x_8 Recirculation Flow
9 : Noise Source f_a
10 : Noise source f_b

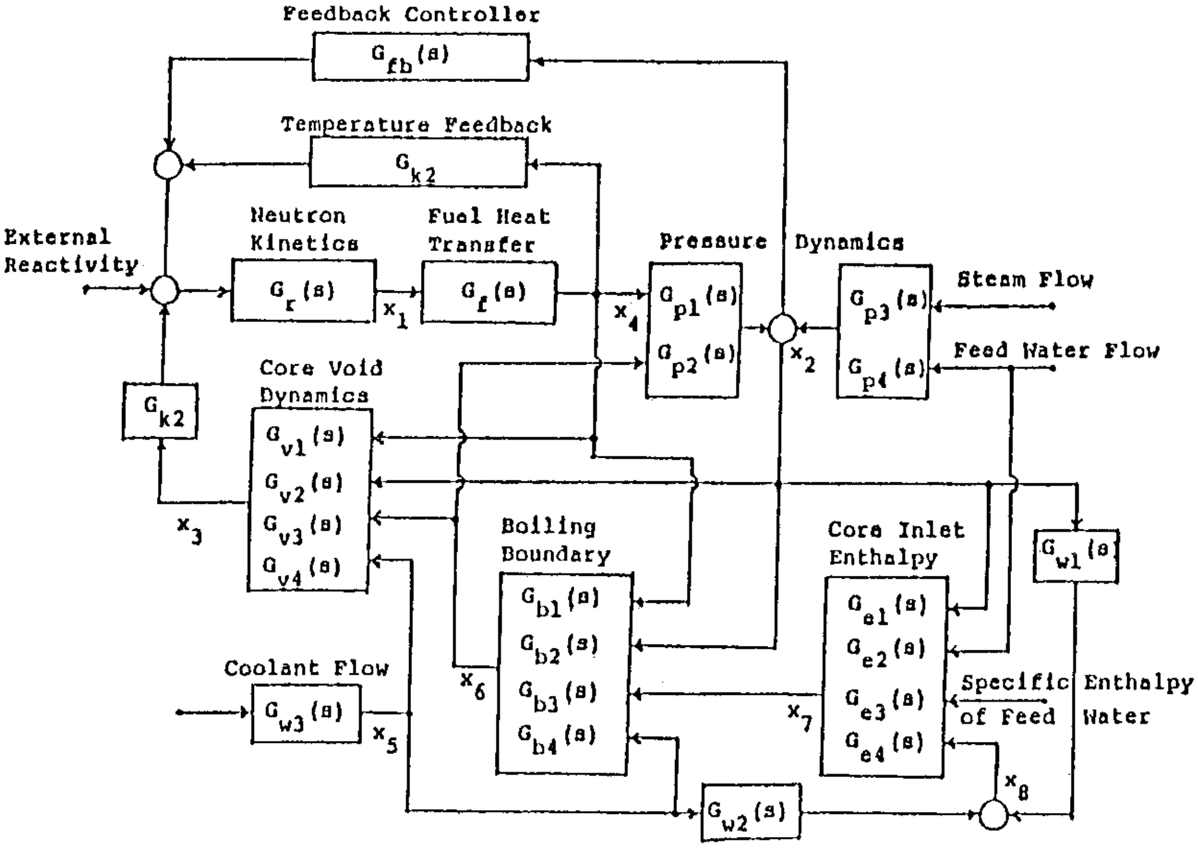


Fig. 1.1 Block diagram of the linearized model of JPDR-II for the artificial synthesized noise.

$G_{fb}(s)$	$k_{fb}[1 + T_{fb}s]^{-3}$	$G_{p1}(s)$	$k_{p1}[1 + T_{p1}s]^{-1}$
$G_f(s)$	$k_{f1}[1+T_{f1}s]^{-1} + k_{f2}[1+T_{f2}s]^{-1}$	$G_{p2}(s)$	$k_{p2}[1 + T_{p2}s]^{-1}$
$G_r(s)$	$k_{r1}s^{-1} + k_{r2}[1+T_{r2}s]^{-1}$	$G_{p3}(s)$	$k_{p3}[1 + T_{p3}s]^{-1}$
G_{k1}	constant	$G_{p4}(s)$	$k_{p4}[1 + T_{p4}s]^{-1}$
G_{k2}	constant	$G_{b1}(s)$	$k_{b1}[1 + T_{b1}s]^{-1}$
$G_{v1}(s)$	$k_{v1}[1+T_{v1}s]^{-1}$	$G_{b2}(s)$	constant
$G_{v2}(s)$	$k_{v2}[a_{v2}+b_{v2}(1+T_{v2}s)^{-1}]$	$G_{b3}(s)$	$k_{b3}\exp(-\tau_d s)$
$G_{v3}(s)$	$k_{v3}[1 + T_{v3}s]^{-1}$	$G_{b4}(s)$	$k_{b4}[1 + T_{b4}s]^{-1}$
$G_{v4}(s)$	$k_{v4}[1 + T_{v4}s]^{-1}$	$G_{e1}(s)$	$k_{e1}G_{e2}(s) + k'_{e1}s$
$G_{w1}(s)$	$k_{w1}[a_{w1} + b_{w2}s]$	$G_{e2}(s)$	$k_{e2}[(1+\lambda_1 s)^{-1}-(1+\lambda_2 s)^{-1}]$
$G_{w2}(s)$	constant	$G_{e3}(s)$	$k_{e3}G_{e2}(s)$
$G_{w3}(s)$	$k_{w3}[1 + T_{w3}s]^{-1}$	$G_{e4}(s)$	$k_{e4}G_{e2}(s)$

Table 1.1 Transfer Functions

2. Borssele Reactor Noise data (Original tape from Dr. E. Türkcan)

Reactor: The reactor of the 450 MW_e power station at Borssele is a PWR with two primary coolant loops, built by KWU.

Experiment:
Date 13-3-1979
Identified as B6/2 E126
P_{th} = 1360 MW
P_e = 447 MW
Boron concentration = 750 ppm.

Detectors: (see fig.a)
Ion-chambers model KNU-42 (Excore)
Incore neutron detectors - Cobalt self-powered neutron detectors (20 cm - sensitive length).

Electronics: See fig. 2.2.

Tape recorder: Ampex type PR 2200. FM, 1" tape.

Data recording: 3 $^3/_4$ ips (dc to 1.25 kHz, S/N = -41 db). Intermediate band. Harmonic distortion 1.5%, 1 volt rms. level.

Content of the data tape:

Footage counter (feet)	Signal contents
4 - 34	- 2000 mV dc
35 - 63	+ 500 mV dc
65 - 93	+ 2000 mV dc
95 - 123	+ 3500 mV dc
125 - 223	White Noise (about 210 mV rms)
225 - 274	Sinus 20 Hz (19.9 Hz about $4V_{tt}$)
275 - 3419	Borssele Reactor Noise Data ≡ E126 (see following table)
3419 - 3440	Zero Input

Table 2.1

Borssele Reactor Noise Data

Data Recording: 3 3/4 ips. footage counter (ft): 275 to 3419 ft.

CHANNEL	DETECTOR Ident.	MEAN (dc in V)	GAIN of Noise Amp.	rms (in V) (0.01 to 32 Hz)
1. In Core	IN 16	3.56	20	0.25
2. Ex Core	D 82	1.59	200	0.48
3. In Core	IN 15	5.01	50	0.29
4. Ex Core	LIN	0.79	200	0.27
5. In Core	IN 14	5.15	50	0.30
6. Ex Core	D 62	1.53	200	0.49
7. In Core	IN 13	5.24	50	0.39
8. Ex Core	D 72	1.59	200	0.53
9. In Core	IN 12	4.75	50	0.38
10. Ex Core	LOG	0.87	200	0.37
11. In Core	IN 11	3.16	100	0.49
12. Ex Core	D 52	1.52	200	0.61
13. Pressure	YA01 P001	0.54	20	0.38
14. Pressure	YA02 P001	0.55	50	0.23

Primary system pressure signals range: 130-150 kgf/cm^2 (50 kgf/cm^2 = 1 volt).

Normalization of data during the analysis:

A. results in Volt or $Volt^2/Hz$:

$$\text{scale A} = \frac{\text{range of ADC in Volt}}{2^x} \times \frac{1}{\text{Gain of Amplifier}}$$

x = number of bits of ADC.

B. Normalized data:

$$\text{scale B} = \text{scale A} \times \frac{1}{\text{mean (in Volts)}}$$

(e.g. for neutron detector signals)

C. Normalization to physical units:

scale C = scale A x Range (in physical units)

e.g. for pressure signals.

Note: Due to the additional filter at in-core neutron detector circuit (Krohn-Hite) one will find:

at 9.2 Hz (reactivity effect) ________
phase between all ex-core n-detectors = 0°
phase between all in-core n-detectors = 0°,
but phase between in-core/ex-core = -55°.

Fig. 2.1

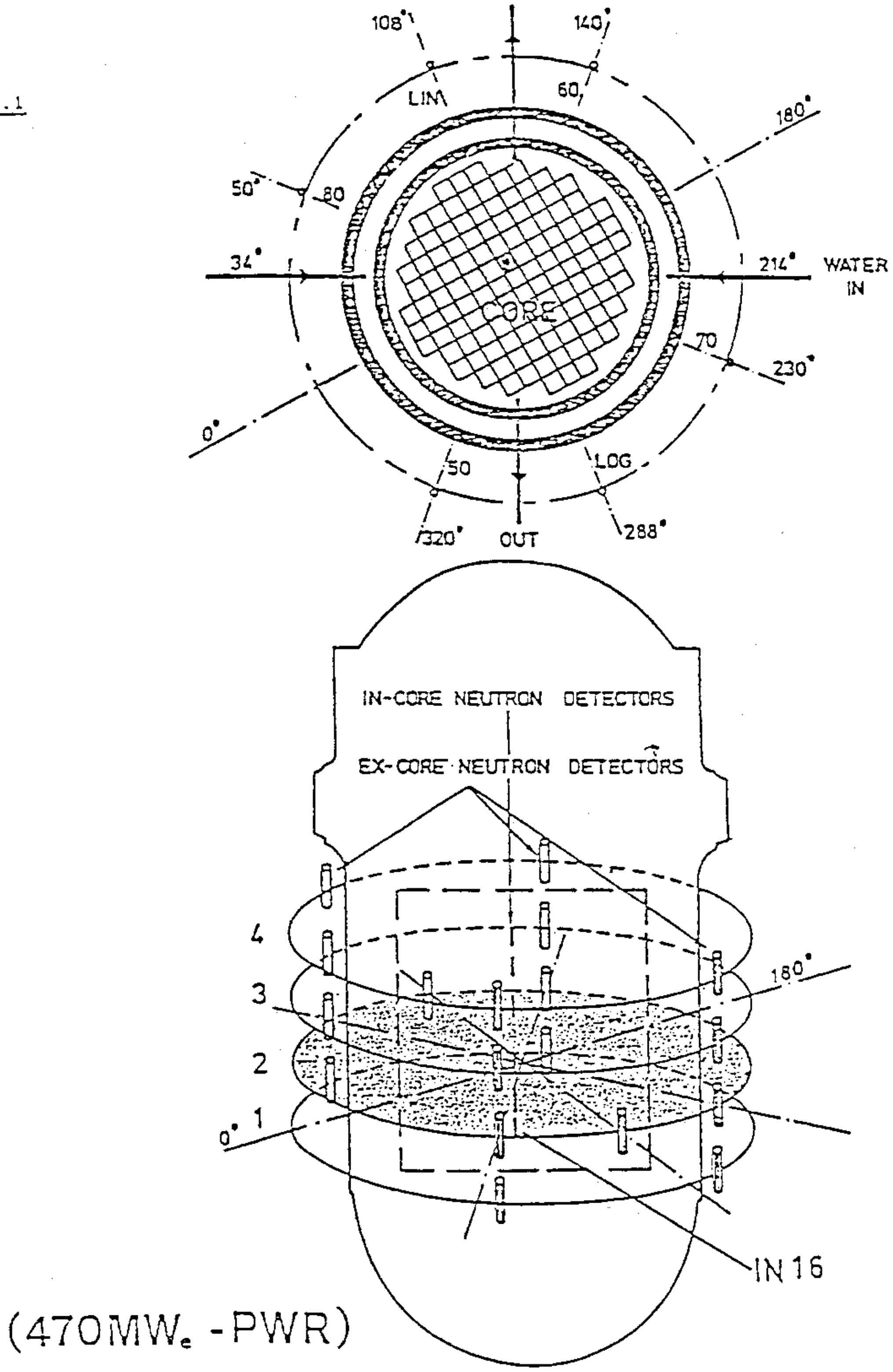
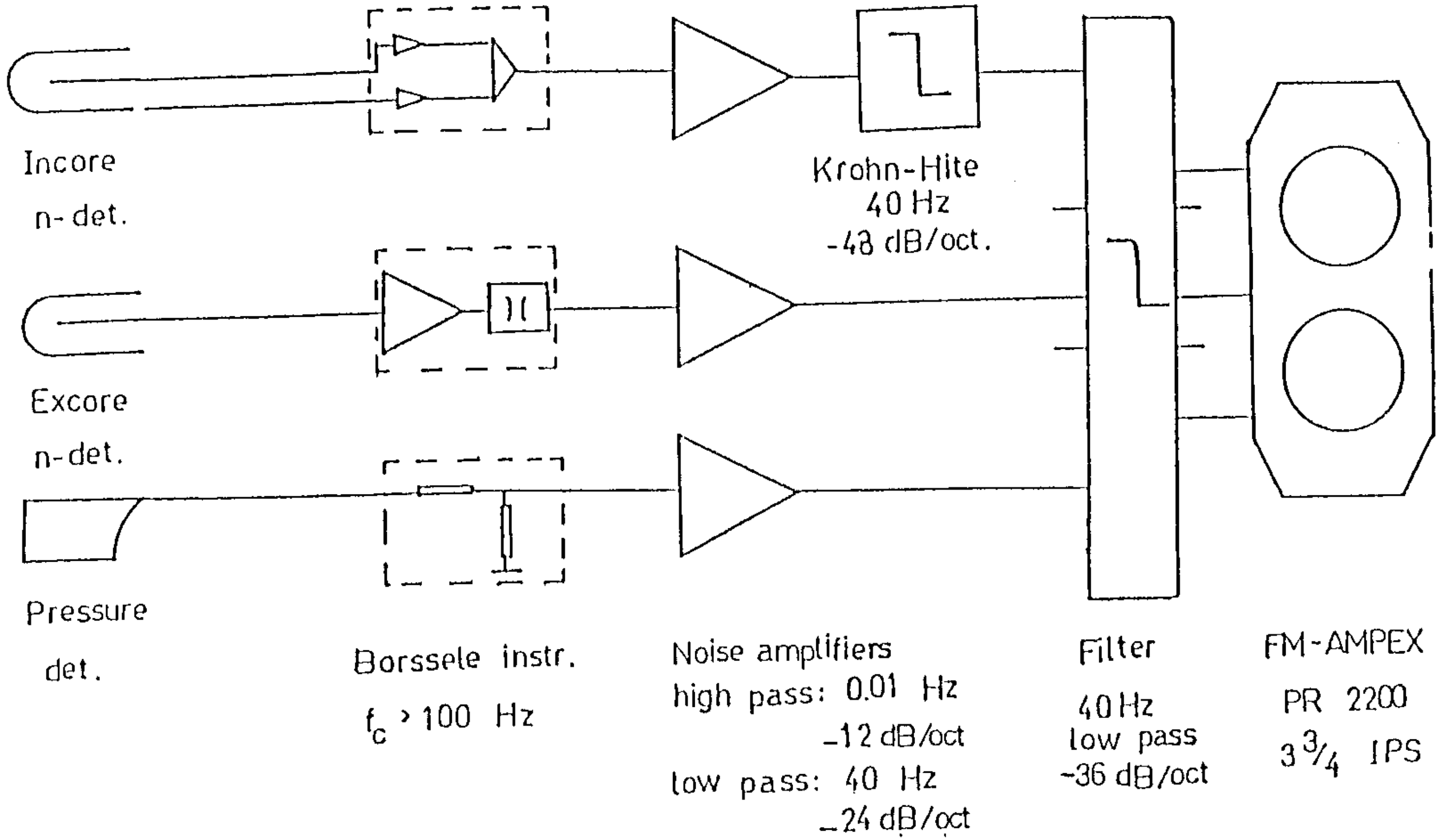

108°
140°
LIN
60
180°
50°
80
34°
214°
WATER IN
CORE
70
230°
0°
50
LOG
320°
OUT
288°
IN-CORE NEUTRON DETECTORS
EX-CORE NEUTRON DETECTORS
4
3
2
1
180°
0°
IN 16
(470MWe -PWR)

Fig. 2.2

BORSSELE EXPERIMENT: Block diagram of thel instrumentation



3. Phénix Noise Data (Original tape from Dr. J. Gourdon)

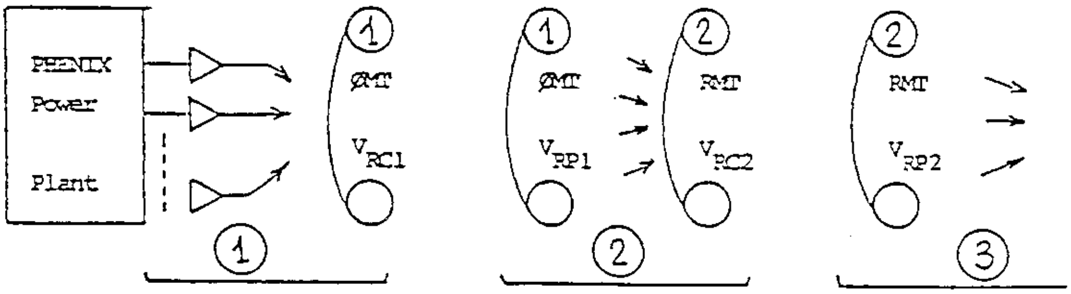
1 - RECORDING TECHNIC

1.1 - Recording Mode (for all the tracks) :

- Frequency modulation "FM"
- Standard IRIG· "IB"
- Output level for nominal modulation : 1.414 volt

1.2 - Recording and reproducing speeds ; magnetic tape recorder

- The tape is the recopy of two distinct recordings
- Specifications, for the tape utilisation, are given in the following table 3.1.1.
- The figure 3.1 describes the recopy process.



①
- * On line operation
- * Real time "t_1"
- * Original magnetic tape "OMT"
- * Speed : V_{RC1}

②
- * Recopy operation
- * Recopy magnetic tape "RMT"
- * Speeds OMT : V_{RP1}
  RMT : V_{RC2}

③
- * Laboratory analysis
- * Laboratory time "t_3
- * Speed : V_{RP2}

Notice the ratio : $\frac{\text{Laboratory time}}{\text{Real time}} = \frac{t3}{t1} = \frac{V_{RP1}}{V_{RC1}} \times \frac{V_{RP2}}{V_{RC2}}$

Fig. 3.1

Table 3.1.1

	ORIGINAL Record speed "VRC1" IPS	Recopy Repro. Speed "VRP1" IPS	operation Record Speed "VRC2" IPS	Laboratry time / Real time = $\frac{t3}{t1}$ (VRP2=labo. Speed)	Signals bandwith in real time domai
first recording	7 1/2 (AMPEX 1300)	60 (Bell Howel 4020)	30 (Bell Howel 4020)	$V_{RP2} \times \frac{4}{15}$	1250 Hz
second recording	(Bell Howell 4020) 15 / 16	(Bell Howel 4020) 60	(Bell Howel 4020) 15	$V_{RP2} \times \frac{64}{15}$	78 Hz

1.3 – Tape description (see para. 1.2)

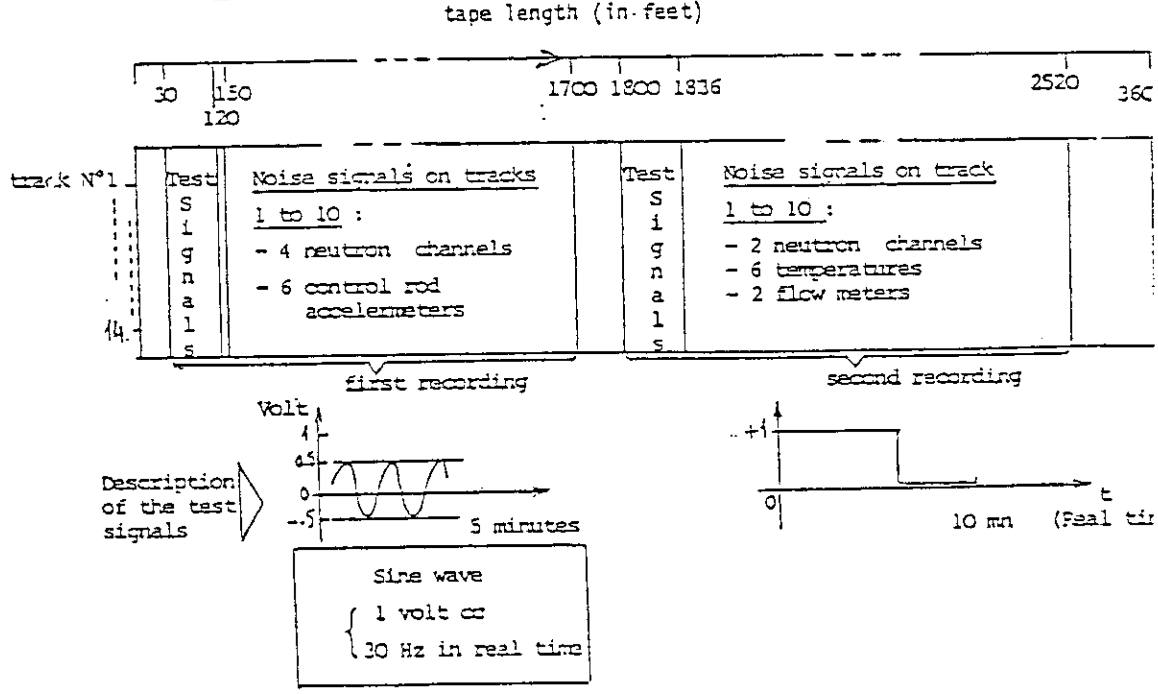
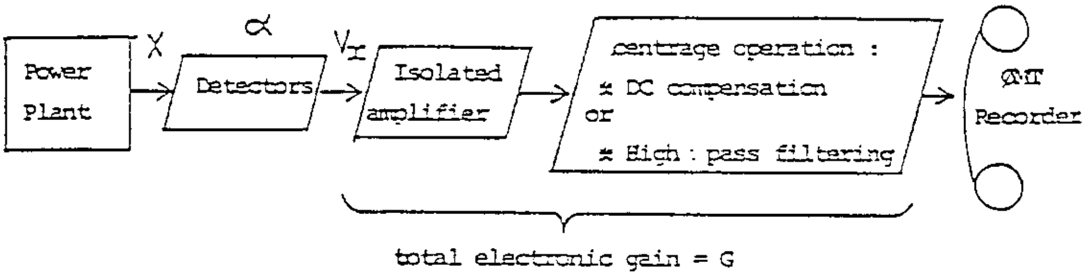


Fig. 3.2

1.4 - Definition of the parameters used and symbols

Fig. 3.3



Five parameters are given for the recording exploitation

1 - total electronic gain ⟶ G

2 - cut of (low pass) frequency of the isolated amplifier ⟶ f_2

3 - High pass frequency or the indication of a DC compensation $\left\{ f_1 \text{ or } DC \right.$

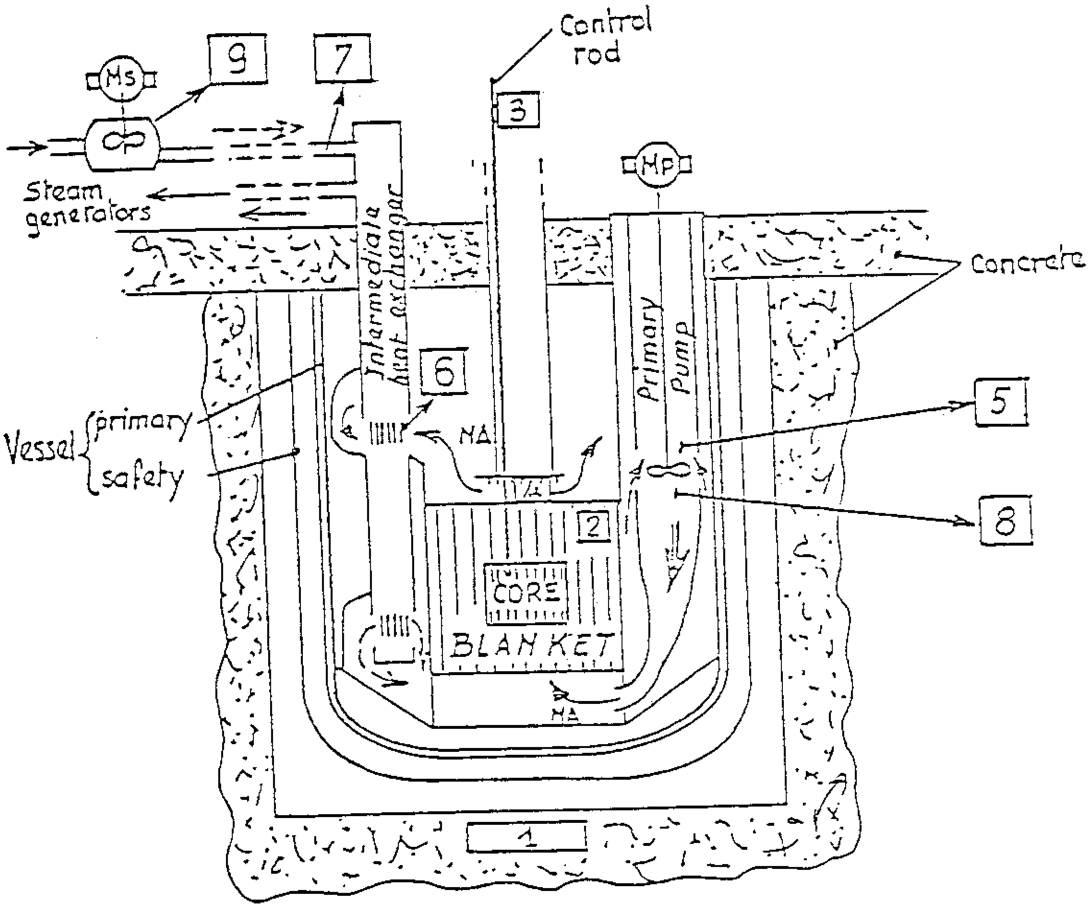
4 - Sensitivity of the detector in "volt [Physical units]"$^{-1}$ α

5 - The mean value in "physical units" or in "volt" $\left\{ \bar{X} \text{ or } \bar{V}_x \right.$

($\bar{V}$ is given before amplification)

2 - DETECTORS DESCRIPTION AND SYMBOLS

2.1 - General view



$\boxed{*}$ Phenix Instrumentation location : the definition of the code number " $\boxed{*}$ " is given in the table 3.2.1.

only some devices are represented :

- 1 between 3 primary pumps
- 1 " 3 secondary pumps
- 1 " 6 control rods
- 1 " 3 intermediate heat exchangers

Fig.3.4 : Schematic view of PHENIX

Table 3.2.1

* Number	Physical definition	Used symbol
1	ion chambers "out of core" and "under the vessel"	Z1 MR 41 Z1 MR 51
2	ion chambers "in core"	Z1 MR 12 Z2 MR 12
3	accelerometers located near the top of the control rod mechanisms	BCMG 01 to BCMG 06
4	oulet temperature of a subassembly	TATA **** code number of the subassembly
5	pump inlet temperature = core inlet temperature	P3 MT 25
6	Intermediate heat exchanger : primary inlet temperature	P1 MT 01
7	Intermediate heat exchanger and secondary loop : secondary inlet temperature	S1 MT 01
8	Primary pump flow meter (electromagnetic)	P1 MQ 02
9	Secondary pump flow meter (electromagnetic)	S1 MQ 01

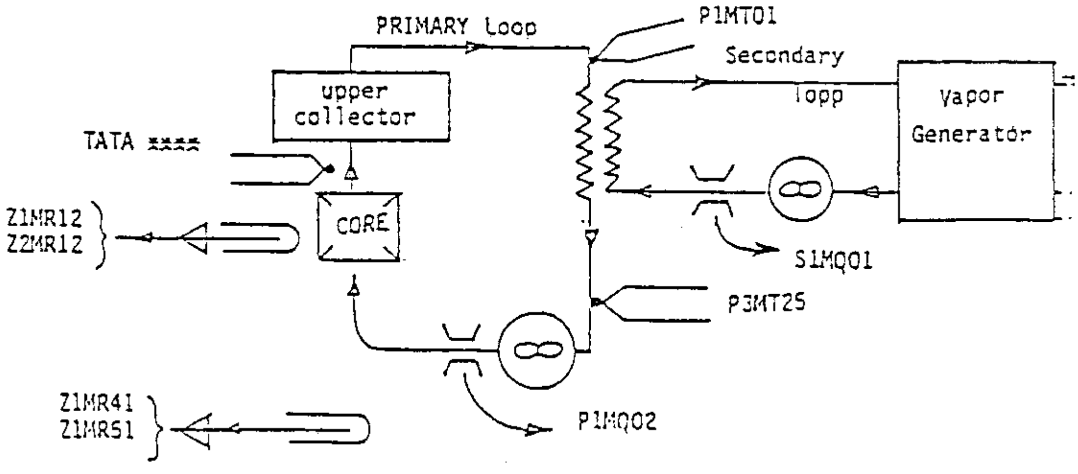


Fig. 3.5 : Bloc scheme representation

2.2 - Some Detectors characteristics

a/ - Temperature

Sensitivity of the chromel/alumel thermocouples : 42.10^{-6} volt.°C^{-1}

Core oulet temperature position : see figure 3.4.

b/ - Neutron detectors

Four ion chambers can be used for noise measurements. The following table or figures give the basic characteristics of these detectors.

Table 3.3.1

Symbol	Technical code	basic characteristics	sensitivity $Ax[nCM^{-2}sec^{-1}]^{-1}$	PHENIX Position
Z1MR41	CC5	γ compensated ion chamber (Bore)	$1,7.10^{-14}$	under the vessel see Figure 3.6
Z1MR51	CC5			
Z1MR12	CFUC02	High temperature Fission chamber (gas cooled)	2.10^{-13}	In core.: see Figure 3.7
Z2MR12	CFUC02			

In all the cases a linear current electronic device is used.

3 - RECORDING TABLES

Table 3.1 - First recording :

30 feet to 1700 feet

(See tables 3.1.1 and 3.2.1)

Track Number	Symbol	G	f_2 [Hz]	f_1 [Hz] or DC	$\overline{X}$ [Physical units]	$\overline{V}$ [Volt]	σ [Volt][Physical unit
1	Z1MR41	20	1000	10^{-2}		9.07	
2	Z1MR51	5	1000	10^{-2}		9.11	
3	Z1MR12	10	1000	10^{-2}		9.46	
4	Z2MR12	20	1000	10^{-2}		5.36	
5	BCMG01			0		0	1 volt/(m sec^{-}
6	BCMG02			0		0	"
7	BCMG03			0		0	"
8	BCMG04			0		0	"
9	BCMG05			0		0	"
10	BCMG06			0		0	"

Table 3.2 - Second recording :

1800 feet to 2520 feet

(See Tables 3.1.1 and 3.2.1)

Track Number	Symbol	G	f_2 (Hz)	f_1(Hz) ou DC	$\overline{X}$ Physical units	$\overline{V}$ Volt	α [Volt/Physical unit]
1	Z1MR41	20	1000	10^{-4}		8.96	
2	Z1MR51	5	1000	10^{-4}		9.10	
3	TATA2018	5000	100	DC	571°C		42.10^{-6} V $°C^{-}$
4	TATA2119	5000	100	DC	614°C		"
5	TATA2024	5000	10	DC	592°C		"
6	P3MT25	10000	10	DC	397°C		"
7	P1MQ02	1000	1000	DC		-9.10^{-3}	
8	S1MQ01	1000	1000	DC		$+9.10^{-3}$	
9	P1MT01	10000	10	DC	568°C		42.10^{-6} V $°C^{-}$
10	S1MT01	20000	10	DC	348°C		"

3.3 - PHENIX operating parameters during these recordings

Date : 1980, october

Thermal Power : 588 MW

Electrical Power : 258 MW

Core temperature rise (mean value) : 168 °C

Rotation speeds of the :

- 3 primary pumps : 820 r/minute
- 3 secondary pumps : 800 r/minute

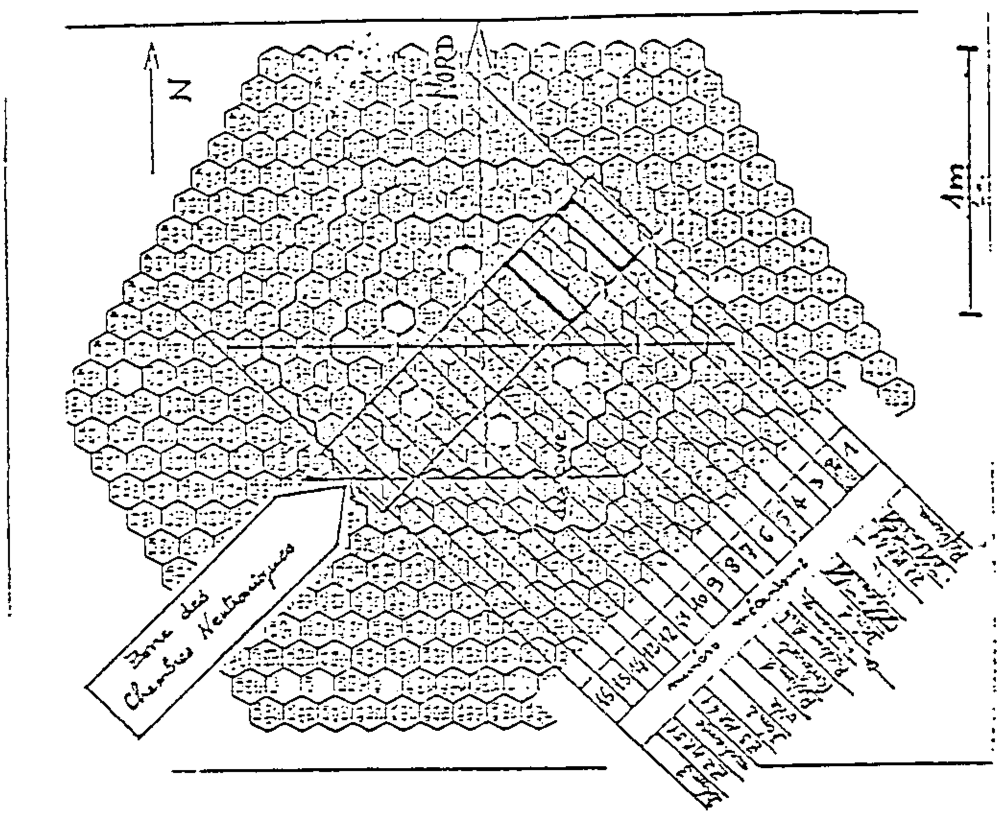
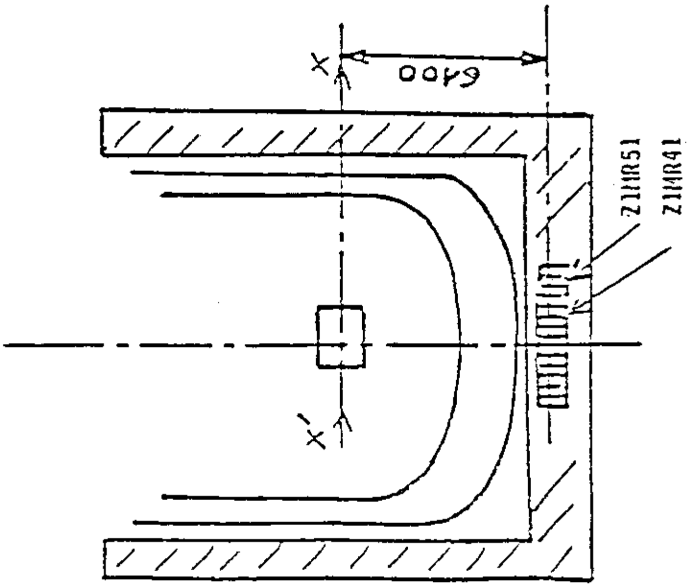
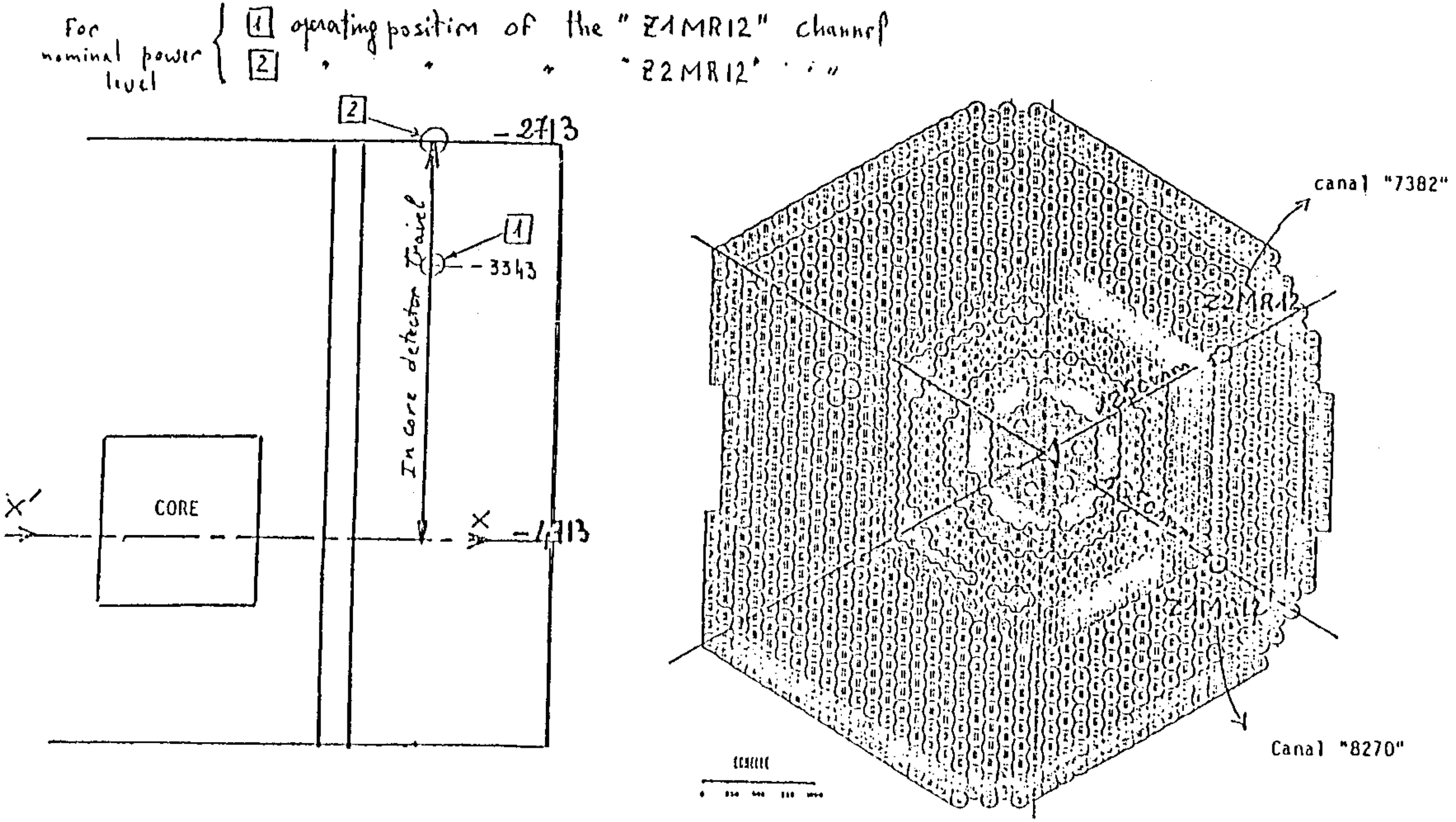


Fig. 3.6



PHENIX : OUT OF CORE
NEUTRON DETECTORS POSITION



PHENIX : IN CORE NEUTRON DETECTOR POSITIONS

Fig. 3.7

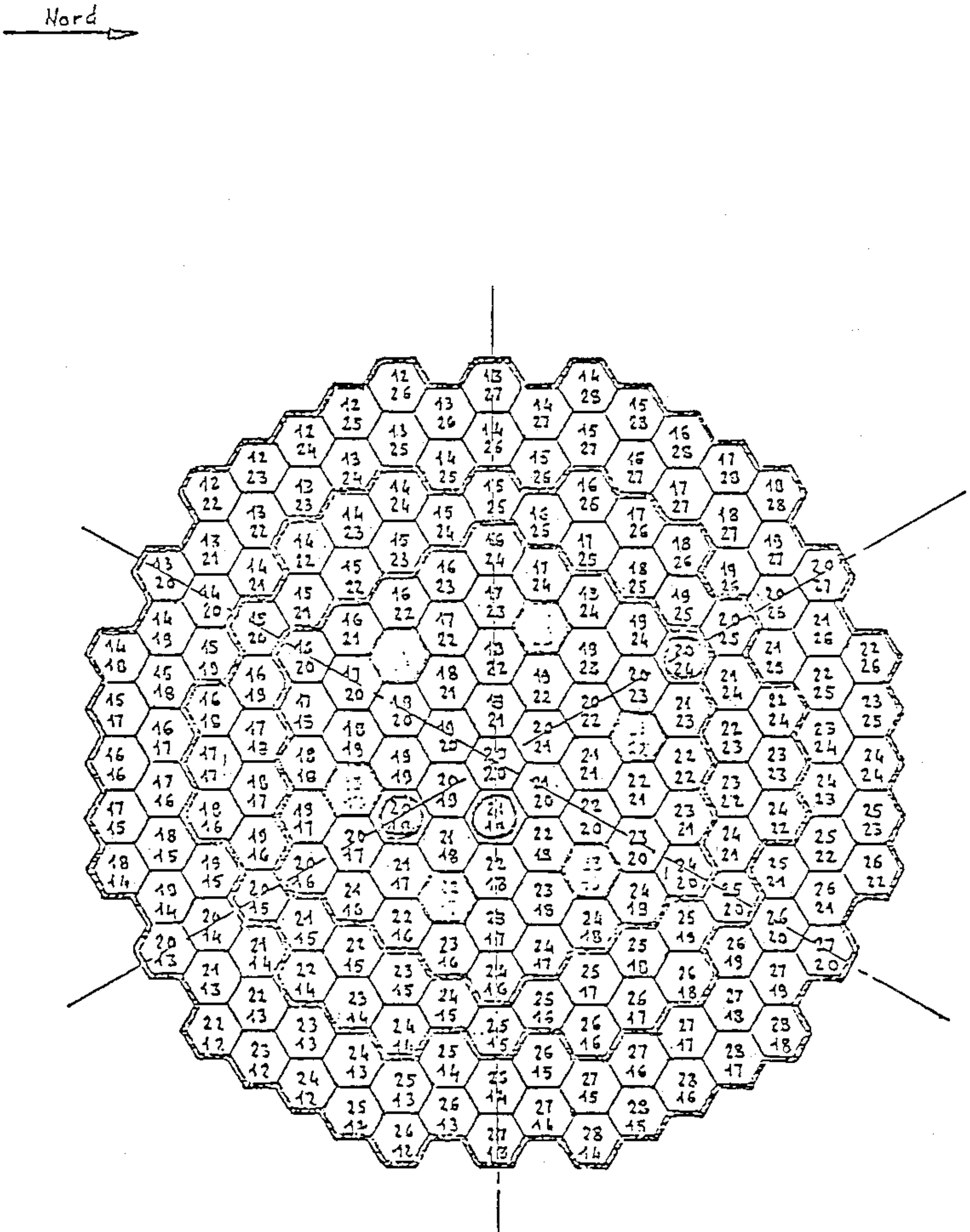
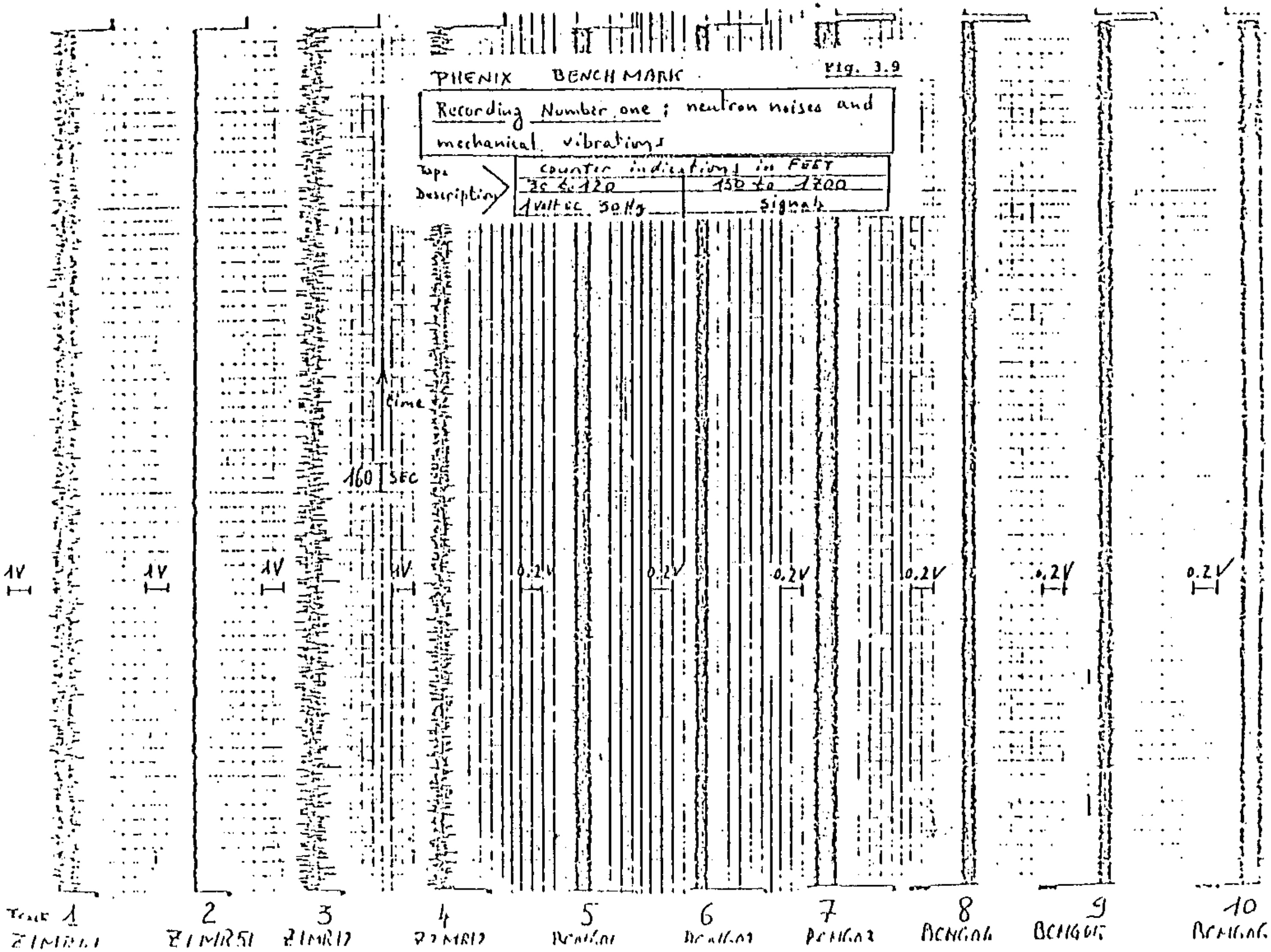


Fig. 3.8 CORE CROSS SECTION : SUBASSEMBLY CODE NUMBER



PHENIX BENCH MARK

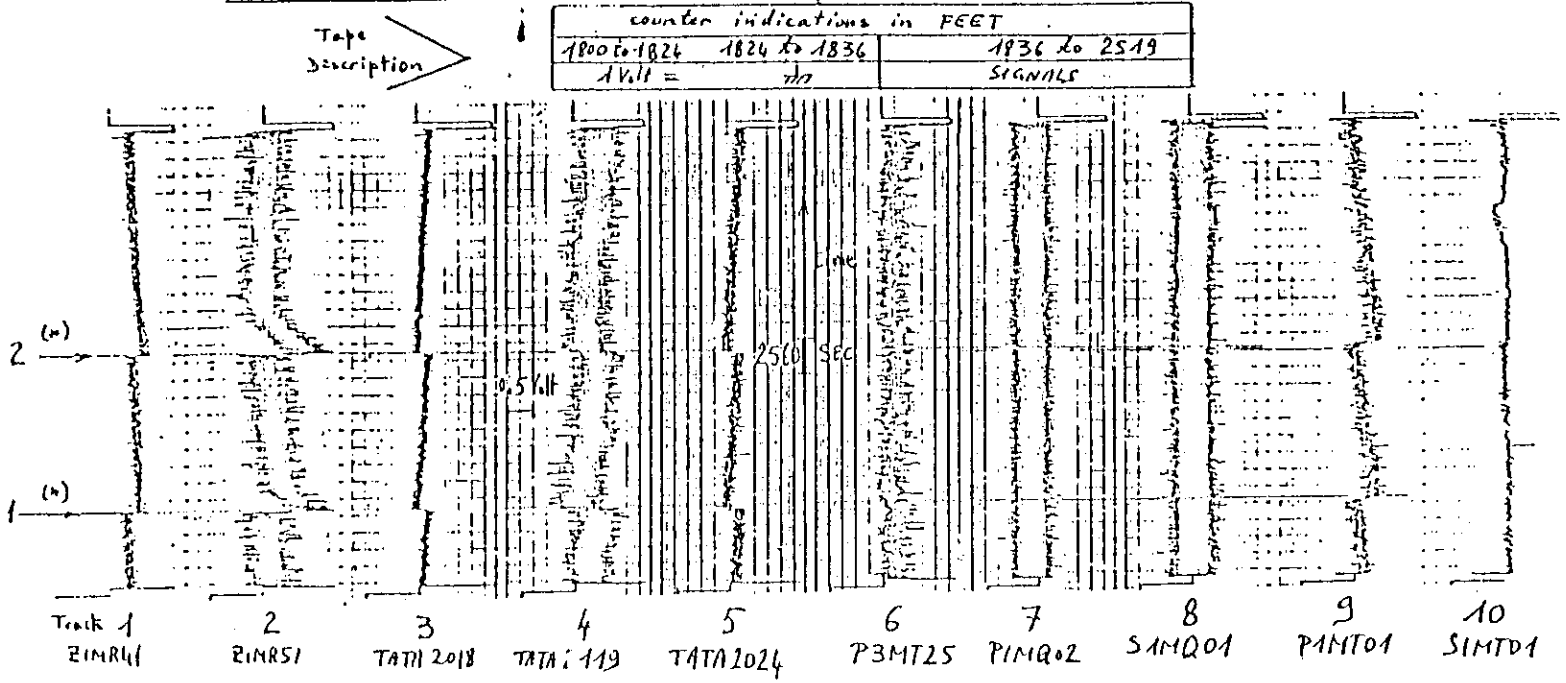
Fig. 3.9

Recording Number one ; neutron noises and mechanical vibrations

Fig. 3.10

PHENIX BENCHMARK

RECORDING NUMBER TWO : neutron noises, temperatures, flow measurements



For all the tracks : "⊢⊣" = 0.5 Volt

"*" events 1 or 2 : due to control rod adjustement (burn-up compensation)

APPENDIX B

Digital Version of the Test Data

A part of the test data was digitized, recorded on a digital magnetic tape and sent to NEA Data Bank. Detailed information on the digitized test data is given in this Appendix.

Reactor Noise Analysis

Benchmark Test for SMORN-III

Digital Version of Analog Test Data

The digital version of the test data was made by digitizing a part of the analog data originally for the SMORN-III benchmark test data through the data processing as shown in Figure 1.

1. Filtering of the analog test data

Taking into account the problem of aliasing which may occur in data sampling, the second order analog low pass filter is utilized before sampling the data. The filter was designed to have cut-off frequency at 64 Hz for the artificial and Borssele data, and at 128 Hz for the Phénix data, respectively.

2. Amplification

In order to reduce quantization error which may place in A/D conversion of the test data, the output signals from analog data recorder were pre-amplified by appropriate factor in each case as shown in Table 1.

3. Sampling

The analog data were fed into digital part of the hybrid computer EAI PACER-600 (ASCII code) through A/D converter with 13 bits. The value 1.0 in sampled data corresponds to that of 1/3 V in the analog data only except for the case of channel 1 in Phénix data, which corresponds to 1/150 V.

3.1 Sampling interval

The data were digitized with sampling intervals, Δt=10 msec for the artificial and Borssele data, and Δt=5 msec for the Phénix data, respectively. The sampling intervals were so determined that the frequency charactristics contained in the analog data might not be distorted by the digitizing procedure within frequency region required for the analysis of the benchmark test.

3.2 Number of sampled data

Because of the limited capacity of the disk memory in PACER-600, only two signals required for the benchmark test were digitized. The number of sampled data is about 167,000/channel, covering only 1/4 or 1/8 of the analog test data as shown in Figure 2.

4. Recording on digital magnetic tape

Using FACOM M-200 computer, the sampled data were converted from ASCII code to EBCDIC code (IBM compatible) and were recorded on the digital magnetic tape.

This digital version of test data consists three data files in the order of the artificial, Borssele and Phénix data. Successive three files are each separated by a "Tape mark". End of the data recording is specified by two Tape marks as shown in Figure 3.

Each file consists of 82 "Blocks". And each Block consists of 32 "Records" One Record is 128 "Words" (512 bytes). The record format is "Fixed Block".

The sampled data in each file were written with the alternate arrangement of channel 1 and channel 2 (or 5) as shown in the bottom of Figure 3. The content can be listed as follows ;

```
      READ(UNIT,10) (A(I),I=1,128)
   10 FORMAT(128A4)
```

The magnetic tape device used for recording the data is 9 tracks and 1,600 BPI.

To summarize ;

TRK	:	9	RECFM	:	FB
BPI	:	1,600	LRECL	:	512 bytes
CODE	:	EBCDIC	BLKSIZE	:	32 records
LABEL	:	NO LABEL	each FILE	:	82 blocks

5. Reference data

The lists of the output data covering only first and second Blocks of each file is attached in Appendix 1. The plotted graphs of three data are shown in Figure 4, 5, 6.

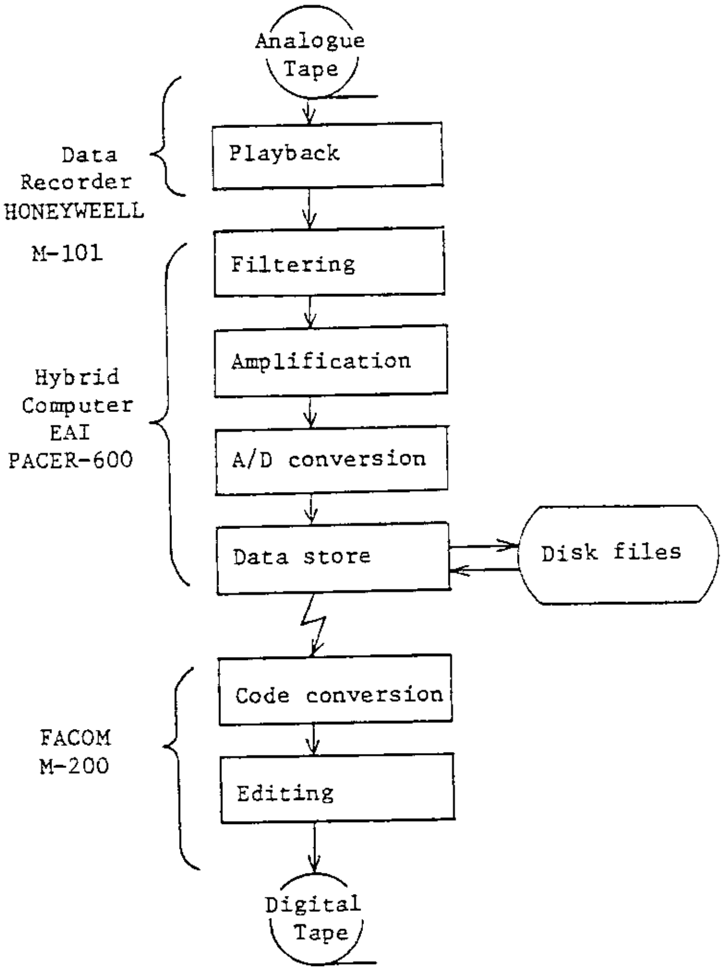
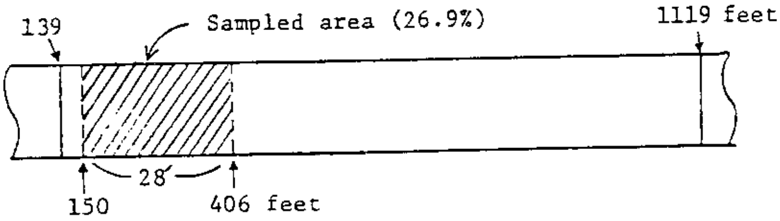


Figure 1 The procedure of making the digital version

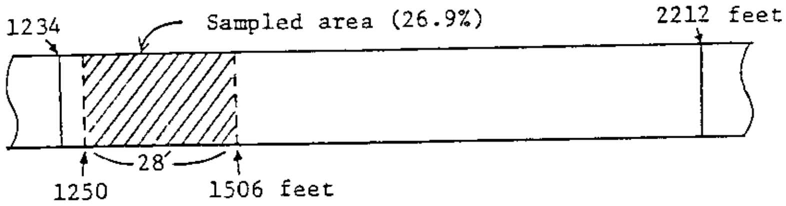
Table 1 Parameters of digitizing

Data set	Analogue tape channel number	Variable name	Amplification factor	LPF Cut-off frequency (Hz)	Sampling interval (msec)	Number of sampled data
Artificial data	1	Neutron density	3.0	64	10	166,877 /channel
	2	Vessel pressure with additive noise	3.0			
Borssele data	1	In-core detector signal (IN-12)	3.0	64	10	166,687 /channel
	2	Ex-core detector signal (LOG)	3.0			
Phénix data	1	Subassembly outlet temperature (TATA2018)	150.0	128	5	167,936 /channel
	5	Ex-core ion chamber (Z1MR51)	3.0			

(1) Artificial data



(2) Borssele data



(3) Phénix data

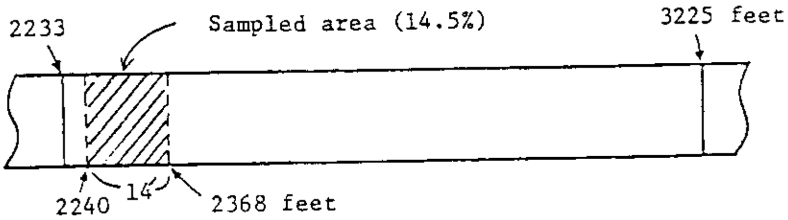


Figure 2 Sampled area in the analogue test tape

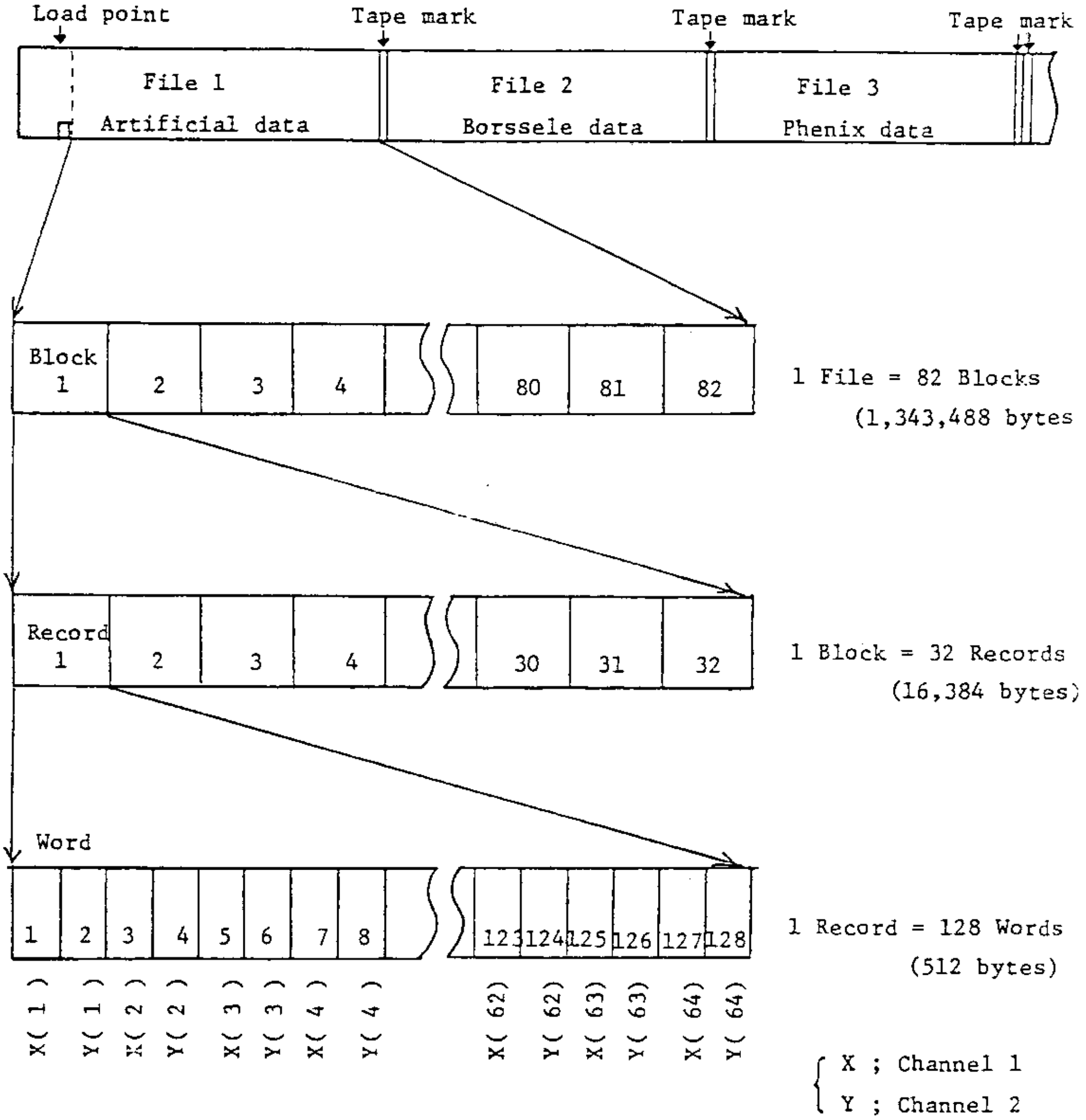


Figure 3 Record format of the digital tape

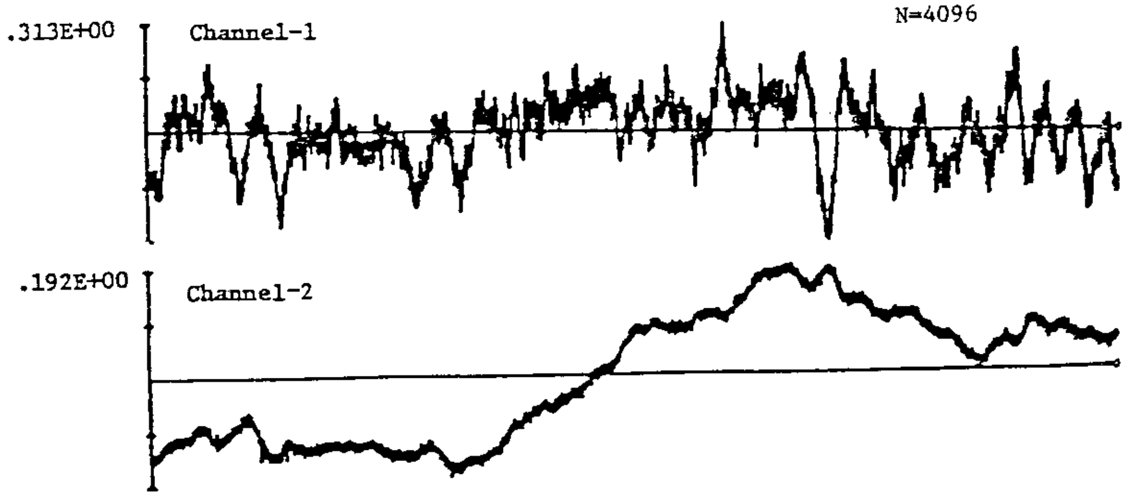


Figure 4 Time series graph of the artificial data (First and second Blocks)

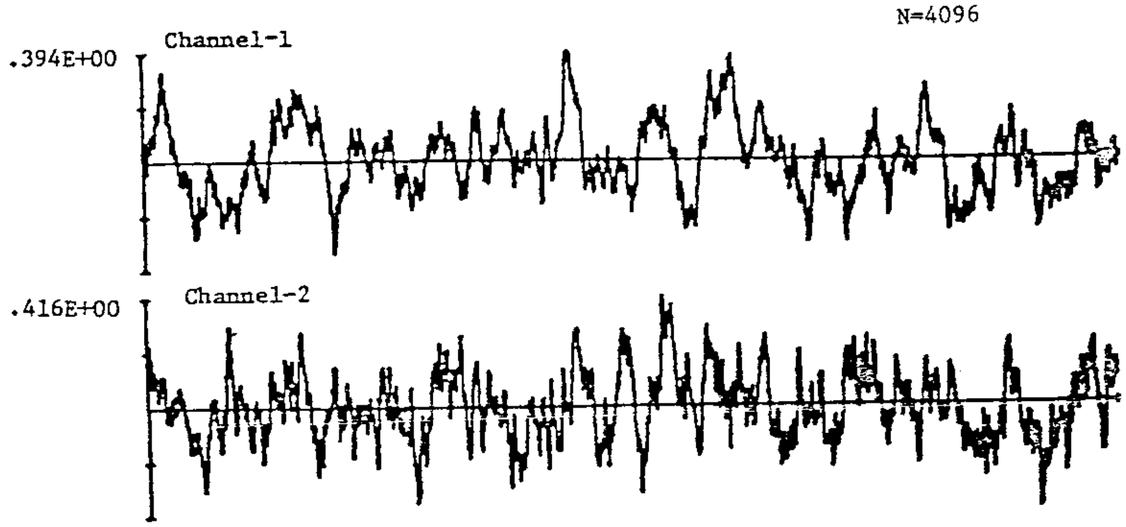


Figure 5 Time series graph of the Borssele data (First and second Blocks)

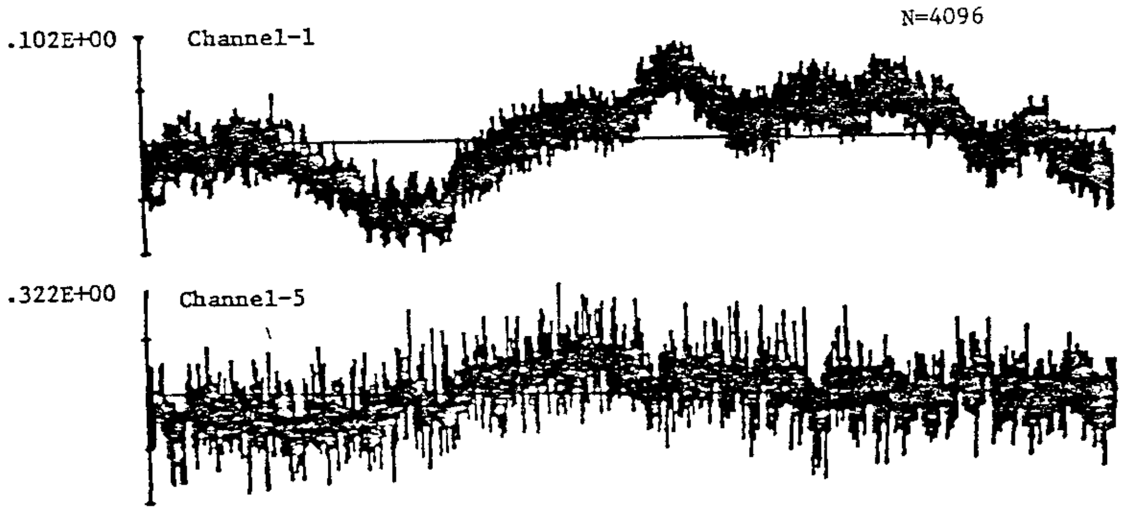


Figure 6 Time series graph of the Phenix data (First and second Blocks)

APPENDIX C

Summary Report on the Benchmark Test Presented at SMORN-III

The summary report given in this Appendix was presented at the final session of SMORN-III as well as at the informal meeting of the benchmark test contributors. A part of this summary report is included in the proceedings of SMORN-III, i.e. Progress in NUCLEAR ENERGY, Vol.9, published by Pergamon Press in 1982.

Summary Report
on
Reactor Noise Analysis Benchmark Test

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Abstract

Reactor noise analysis benchmark test has been carried out in conjunction with SMORN-III. The test is aimed at computational rather than physical benchmark. Three types of the source data are analyzed: an artificial noise generated by computer simulation of BWR, real reactor noises of a PWR and a FBR. Twenty three groups of specialists contributed to the test. Generally speaking, the computed results agreed one other quite well. Some discrepancies were observed in a few exceptional cases. Through this experience clues for making reliable data base of the reactor noise are obtained and we are encouraged to proceed to a physical benchmark test.

Keywords

Reactor noise, power spectral density, correlation function, coherency, PWR, FBR.

Objective

The objective of this benchmark test is to make comparison among the results obtained for identical test data by different methods for the noise data analysis and thereby to identify data processing problems to be solved before a reliable data base of the processed reactor noise can be established.

The reactor noise analysis may be divided into two stages. First the source data are processed, in some way or other, to obtain the statistical descriptors, such as the power spectral density, the correlation function, the coherency and so on. Then the physical interpretation of these descriptors leads to the physical conclusion: the parameter estimation, the anomaly detection, the reactor noise model and so forth. The present benchmark test is limited to the first stage, and thus it is a "computational" rather than "physical" benchmark. Such a test should proceede a physical benchmark test which may be a topic of some future meeting.

Arrangements of the Test

The arrangements of this benchmark test was made under cooperation of a number of specialists.

Dr. Morishima of Kyoto University has long been working on the BWR noise model. He has shown that, if suitable noise sources are assumed in the simplified model of JPDR-II developed in JAERI, the computed power spectral densities agreed with those by experiments. It was decided, therefore, to adopt this model for synthesizing an artificial noise. The model was slightly modified for easiness of simulation. The artificial noise was generated with the JAERI hybrid computer by Dr. Yamada of Osaka University and graduate students from Osaka and Kyoto Universities, in collaboration with the JAERI staff.

Dr. Turkcan of ECN-Petten supplied the noise data of the Borssele reactor, a 450 MWe PWR.

Dr. Gourdon of CEA/CEN-Cadarache supplied the noise data of the Phenix reactor, a 260 MWe FBR.

Thus three sets of source data, one artificial and two real reactor noise, were available for the test. They were compiled and recorded on the magnetic tape (1 inch wide, 14 channels, 3600 feet long) in the order as shown in Figure 1, where

A: Checking signals at the beginning of data copying.
B: Artificial noise data with the original calibration signals.
C: Borssele reactor noise data with the original calibration signals.
D: Phenix reactor noise data with the original calibration signals.
E: Checking signals at the end of data copying.

The contents of each noise data are shown in Table 1.

Since the recording speed of the original tapes were not the same, the conversion of speed was necessary to unify the speed in such a way that the recorded data could be reproduced in real-time when the tape was played back at 1-7/8 ips in Intermediate Band (IRIG band).

The Herculean task of recording, converting the speed of, and duplicating the data tape was performed by Mr. Shinohara and his staff at JAERI. Moreover, they tested each and every real of the duplicated tapes before dispatching. The tests included evaluation of the rms value and the power spectral densities and also the visual inspection by recording on a chart recorder. They noticed that some amount of high frequency recording noise had mixed into the original noise data in the course of the above mentioned dubbing process. Its effect, however, was judged to be insignificant for the present computational benchmark test.

In the meantime the application forms were distributed through the member organization of NEA. Application was made by 25 groups of specialists.

A reel of data tape was sent to each of these groups, together with the task description and a questionnaire about the analysis. Twenty three groups submitted their results of analysis. The list of the contributors is given in Appendix 1.

The technical program committee met several times to fix the details of the arrangements and to draft the task description and the questionnaire. Dr. Kishida of Gifu University as well as Drs. Yamada, and Morishima joined in these meetings.

Tasks

Although the tape contained various data as shown in Table 1, only the data recorded in Channels 1 and 2 of the artificial and Borssele data, and Channels 1 and 5 of the Phenix data, have been used for the present test. As it is intended to make a computational benchmark test, the data have been chosen from the numerical but not from the reactor physics point of view.

The purpose of including data not used in the present test is to convey to the applicants some parts of the original source data which may by used in a future physical benchmark test if it is considered to be useful.

For each of the three sets of noise data, the applicants were requested to report the standard deviation and the following functions in graphical form:

1) Normalized Auto-Correlation Functions: $\overline{C}_{11}(T)$, $\overline{C}_{22}(T)$
2) Normalized Cross-Correlation Function: $\overline{C}_{12}(T)$
3) Auto Power Spectral Density Functions: $P_{11}(f)$, $P_{22}(f)$
4) Cross Power Spectral Density Function: $P_{12}(f)$
5) Coherence Function: $\mathrm{Coh}^2_{12}(f)$

where the suffix 2 should be replaced by suffix 5 in the case of the Phenix data.

For random variables $x_i(t)$, the functions in the tasks are defined as follows:

1) Normalized Auto-Correlation Function: $\overline{C}_{ii}(T)$

$$\overline{C}_{ii}(T) = C_{ii}(T) / C_{ii}(0)$$

where $C_{ii}(T) = E[x_i(t)x_i(t+T)] - \{E[x_i(t)]\}^2$

2) Normalized Cross-Correlation Function: $\overline{C}_{12}(T)$

$$\overline{C}_{12}(T) = C_{12}(T) / \sqrt{C_{11}(0)\ C_{22}(0)}$$

where $C_{12}(T) = E[x_1(t)x_2(t+T)] - E[x_1(t)]E[x_2(t)]$

3) Auto Power Spectral Density Function: $P_{ii}(f)$

$$P_{ii}(f) = \int_{-\infty}^{\infty} C_{ii}(T)\exp(-j2\pi f)\,dT$$

4) Cross Power Spectral Density Function: $P_{12}(f)$

$$|P_{12}(f)| = \sqrt{\{Re[p_{12}(f)]\}^2 + \{Im[P_{12}(f)]\}^2} \quad : \text{(magnitude)}$$

$$\angle P_{12}(f) = \tan^{-1}\{Im[P_{12}(f)] \;/\; Re[P_{12}(f)]\} \quad : \text{(phase)}$$

$$-\pi \leq \angle P_{12}(f) \leq +\pi \quad \text{(in the sense of ATAN2 in FORTRAN)}$$

where $P_{12}(f) = \int_{-\infty}^{\infty} C_{12}(T)\exp(-j2\pi f)dT$

5) Coherence Function: $Coh_{12}^2(f)$

$$Coh_{12}^2(f) = |P_{12}(f)|^2 \;/\; P_{11}(f)P_{22}(f)$$

The power spectral density functions should be presented for the frequency range from 5×10^{-3} Hz to 5x10 Hz. In addition, to facilitate the detailed comparison, graphical data in an expanded scale were requested for the frequency range from 0.2 to 2.0 Hz for the artificial noise, from 2.0 to 20 Hz for the Borssele noise and from 0.1 to 1.0 Hz for the Phenix noise, respectively.

Normalized correlation functions should be presented for the lag time from 0 to 10 sec. If the correlation function does not decay sufficiently at the lag time of 10 sec., another graph should be added in a contracted scale for 0 ∿ 100 sec.

Location of the data points computed should be indicated in graphs or in the form of a list.

The applicants were requested to present their results in the specified format. They were also requested to fill in a questionnaire about their method of analysis. The questionnaire is included in Appendix 2.

Summary of Methods of Data Analysis

The important factors concerning the methods of data analysis are summarized in Table 2. Identification symbols, A through X, are assigned, in an arbitrary order, to the contributors.

Most of the contributors analyzed the analog data tape distributed by JAERI. A few of them used the tape digitized by JAERI, and a few others duplicated for themselves. Almost all the contributors analyzed all the three sets of noise.

Every group adopted the digital processing. The number of bits for the analog-to-digital conversion scatters between 10 and 14 bits.

As for the methods used for analysis, those who use the fast Fourier transform consists the majority (18 groups). Numbers of contributions by other methods are 2 by Blackman-Tukey method, 4 by Auto-regressive model fitting, 2 by Auto-regressive moving average model fitting and 1 by maximum entropy method, respectively.

Commercially available analyzing equipments are used by 6 groups. The rest of the contributors contrives their own systems.

Of course all the groups use the anti-aliasing low-pass filters. Nearly half of the contributors included pre-processing of the source data, either linear trend removal or high-pass filtering.

It was requested to obtain the power spectral densities over a frequency range of 4 decades ($5x10^3 \sim 50$ Hz). Since it is very difficult to cover the whole range by a single analysis, the contributors either analyzed only a portion of it, or divided it into several portions and analyzed each portion separately. The division of the range and the related information are shown in the latter part of Table 2.

Comparison of Results

The contributed estimates of the standard deviation of noise data are shown in Table 3. Two problems arised in connection to the comparison of results in graphical form. A few contributors did not observe the format specification. It was impossible to redraw the graphs according tp the specified format since the time for reviewing the results was rather limited. Therefore such contributions were compared with others only by inspection and are not included in the following figures.

In the task description, the normalization of the power spectral densities was not explicitly specified. Therefore, the comparison of PSD's was made with respect to their relative magnitude, disregarding their absolute values.

Results by the group "B" differs drastically from all the others. The group "B" used ARMA model fitting method. They did not report the order of the model they fitted. Apparently they fitted a model of a rather low order for the whole four decades of frequency range. Anyway their results are not included in the figures either.

As shown in Table 3, the estimated values of standard deviation by different contributors are not quite the same, reflecting perhaps the different choices of the frequency range, the data length, the filter characteristics and so forth.

Only a few of the comparisons of graphs are included in the present report. The first one is the APSD of the artificial noise Channel 1. As shown in Figure 2 the results by different contributors agreed fairly well.

As for the autocorrelation function of the same data, most of the results agreed well as shown in Figure 3. Results by the groups E, P and S are slightly different. The negative correlation around the time lag of 1 sec. is more pronounced in the results by H, N and W. One possible explanation for this is the effect of the high-pass filters they used.

In Figure 4 the APSD of the Borssele noise Channel 2 is compared in an expanded scale. The agreement among most of the FFT results are rather good as shown in Figure 4-1. Some difference is observed in H and Q. (Figure 4-2) The results by other methods are compared in Figures 4-3 through 4-8. In the results by S an additional peak appears around 5.5 Hz. (Figures 4-4 and 4-5). These results are obtained from a short data of 40 sec. Probably the peak is a peculiarity of this particular portion of the noise data.

The APSD of the Phenix noise Channel 1 is compared in the Figure 5. They are in quite close agreement. On the other hand autocorrelation functions of the same noise differ widely as shown in Figure 6. This is the largest difference observed throughout the benchmark test.

Several contributors noticed that the Phenix data were not stationary. The signal (reactor noise) to noise (recording noise, etc.) ratio is not very good either. These facts seem to contribute to the above-mentioned discrepancies among the results.

Dr. Kryter of ORNL commented on this problem more specifically from the FFT view point. His comment is very valuable and, therefore, is included here.

Dr. Kryter's comment

The answer, I believe, lies in the facts that the signals in question (Phenix) were (1) dominated by very low-frequency noise components, and (2) showed evidence of nonstationarity within the 105-minute analog data record supplied to benchmark participants. Addressing these points, in turn, in greater detail:

1. The shape of the correlation functions at large lag (τ) values (say, 20-100s) is determined largely by the very low-frequency content (including DC, if any) of the signals. This implies, among other things, that preprocessing operations performed on the data (e.g., removal of mean and/or trend) may change the correlation function shape drastically, depending on the preprocessing procedure used. Likewise, the necessity of partitioning the data into "blocks" of manageable size for the application of the FFT algorithm implies the introduction of a low-frequency cutoff (highpass filter) that is on the order of the reciprocal of the time represented by one datablock, i.e., frequencies lower than this are "lost" to the subsequent operations. These procedure-sensitive losses are not evident in the PSDs, on the contrary, because the entire long-lag region of the correlation function is essentially mapped into the one or two lowest frequency points of the power spectrum, and the difference becomes unnoticeable.

It is also worth mentioning that the sampling rate (and associated analog antialiasing low-pass filtering applied to the signal before digitization) chosen in computing correlation functions via the FFT route likewise introduces a high-frequency cutoff to the resulting $C(\tau)$, which explains why the various participants produced different answers in the vicinity of the origin ($\tau=0$), since the correlation function in this region is determined largely by the signal's high-frequency content.

To summarize, the choices of sampling rate and partitioning blocksize which are necessitated by the FFT approach to computation of correlation functions (auto- and cross-) introduce high- and low-frequency restrictions to the data bandwidth that may go unrecognized and, moreover, are not contained in the fundamental definition of the correlation function as a mean lagged product of signals having unrestricted bandwidth. Therefore, care should be exercised to insure that important frequency regions of the signal are not inadvertently lost in the data treatment when using trend removal and/or FFT.

2. Experimentally-determined uncertainty estimates for the correlation functions (obtained by recording the datablock-by-datablock variation of the results) indicated that the results were very untrustworthy, owing to non-stationarity (e.g., the error bar for C(20 s) 0.7 extended from 0.4 to almost 1.0). Since all benchmark problem participants did not choose to analyze the entire data record provided on magnetic tape, it is not surprising that their results show poor agreement--the answer obtained depends upon the particular stretch of tape analyzed.

Concluding Remarks

On the whole, the benchmark test was successful. In many cases the agreement of the results by different contributors are satisfactory. The difficulty with the low signal-to-noise ratio and the nonstationarity is demonstrated.

More details about the data processing should have been inquired in the questionnaire. Some of our questions were not detailed enough and it is feared that this caused misunderstanding among the contributors.

An informal meeting of the contributors was held during SMORN-III. It is agreed to proceed to some kind of physical benchmark test in near future.

Acknowledgements

Dr. Yamada, his students and Mr. Hayashi of JAERI prepared the tables and figures for this summary. The author acknowledges their tremendous help. Thanks are also due to Dr. Kryter for his valuable comments.

Appendix 1 List of the contributors

Country	Name	Organization
France	Bernard, P. Cloue, J. Messainguiral, C.	CEA/CEN-Cadarache
France	Leguillou, G. Gourdon, J.	CEA/CEN-Cadarache
F.R. of Germany	Bauernfeind, V. Rösler, H. Sädtler, E. Wach, D.	GRS-Garching
F.R. of Germany	Massier, H.	KFZ-Karlsruhe
Hungary	Valko, J.	HAS/CRIS-Budapest
Italy	Federico, A. Galli, C.	CNEN-Roma
Italy	Giovannini, R. Marseguerra, M. Martinelli, T. Motta, M. Taglienti, S.	CNEN-Bologna CNEN-Roma*
Japan	Hayashi, K.	JAERI-Tokai
Japan	Morishima, N. Takeuchi, Y.	Kyoto U.
Japan	Kimura, Y. Nishihara, H.	RRI of Kyoto U.
Japan	Yamada, S. Kishida, K.* Nishimura, T. Bekki, K.	Osaka U. Gifu U.*
Japan	Kuroda, Y.	Tokai U.
Japan	Saito, K. Konno, H. Fujita, H.	U. of Tsukuba
Japan	Fujita, Y. Ozaki, H.	MAPI
Japan	Tamaoki, T.	NAIG

Netherlands	Kleiss, E.B.J.	IRI-Delft
Netherlands	Türkcan, E.	ECN-Petten
Netherlands	Van der Veer	NV KEMA
Sweden	Åkerhielm, F.	Studsvik
Sweden	Bergdahl, B-G.	Studsvik
U.K.	Halliwell Rowley	UKAEA-Risley
U.S.A.	Kryter, R.C.	ORNL
U.S.A.	Ouyang, M.S. Wu, S.M.	U. of Wisconsin-Madison

Appendix 2 Questionnaire

Name: ______________________________
Organization: ______________________________
Business Address: ______________________________

1. From where did you obtain the test data?
   - (a) ☐ JAERI : identification number of the tape ________
   - (b) ☐ NEA Data Bank
   - (c) ☐ Others: specify the source ______________

2. If the test data analyzed is in analog form, please write the model and its main specifications of the data recorder used for playing back the tape. ______________________________

3. If the source noise data analyzed is in analog form, please answer how you processed the data.
   - (a) ☐ processed in analog form throughout the analysis.
   - (b) ☐ processed in digital form except for analog-digital conversion of the source noise data at the outset of the analysis.
   - (c) ☐ combination of analog and digital processings.

   If your answer is (b) or (c), please write the number of bits for quantization of the analog noise data. ______________

4. The system used for analyzing the data is
   - (a) ☐ commercially available, model of the analyzer ________
   - (b) ☐ specially organized by yourself.

5. Please draw the block diagram of your data analyzing system.

6. Does your analysis include pre-processing of the source noise data?
   - (a) ☐ Yes
   - (b) ☐ No

   If your answer is "Yes", please specify the type of pre-processing.

   ____

7. What type of method did you use for analyzing the data?
   - (a) ☐ Blackman-Tukey method
   - (b) ☐ Fast or Direct Fourier Transform method
   - (c) ☐ Auto-regressive (moving average) model fitting
   - (d) ☐ Maximum entropy method
   - (e) ☐ Others

   Please state the specific feature of your algorithm, the order of the AR model, the criterion for determination of the order of the model, etc. ______________________________

8. Please write your analyzing conditions in the form of the table attached with this questionnaire. If the space is not enough, please use separate sheets for additional information.

   Directions for filling the table.

   (a) Since the frequency resolution depends upon the analyzing method, please specify the definition of the frequency resolution which you used.

   (b) If the data analyzed is in analog form, the data length used for an analysis should be expressed by the time spent for retrieving the analog data required for an analysis at the playing back speed of 1-7/8 ips.

   (c) Please write in columns (7) and (8) only identification numbers of your description of the filter (F) and window (W) such as F1, F2, F3, or W1, W2, W3, etc., and it is requested to use separate sheets for describing full information concerning filters and windows such as transfer functions of filters, correlation functions of windows or graphical presentations of their characteristics.

The name of the variable: ____________________

(1) Frequency range [Hz]	(2) Sampling rate [1/sec]	(3) Number of averaging	(4) Data length used for an analysis [sec]	(5) Total length of analyzed data [sec]	(6) Frequency resolution [Hz]	(7) Type of filter analog or digital	(8) Type of window	(9) play back speed of the tape [ips]	(10) Maximum correlation lag [sec]
						analog digital			
						analog digital			
						analog digital			
						analog digital			
						analog digital			
Total frequency range analyzed is from Hz to Hz.									

9. Standard deviation of the noise obtained.

10. Error evaluation (optional).

    Please comment on the error evaluation of your results, and superimpose the error-bar on your graphical data if possible.

11. Please write other findings if any.

12. Please write your comments and suggestions concerning the benchmark test.

TABLE 1. CONTENTS OF NOISE DATA

1. Artificial noise

Channel No. 1: neutron density
2: vessel pressure with additive noise
3: inlet water velocity
4: location of boiling boundary
5: heat flux per unit length
6: inlet water enthalpy
7: recirculation flow
8: void volume in core
9: noise source f_2
10: noise source f_{10}

2. Borssele reactor noise data

Channel No.		
1:	in-core detector signal-	(IN 12)
2:	ex-core detector signal	(LOG)
3:	in-core	(IN 15)
4:	ex-core	(LIN)
5:	in-core	(IN 14)
6:	ex-core	(D 62)
7:	in-core	(IN 13)
8:	ex-core	(D 72)
9:	in-core	(IN 16)
10:	ex-core	(D 82)
11:	in-core	(IN 11)
12:	ex-core	(D 52))
13:	pressure	(YA01 P001)
14:	pressure	(YA02 P001)

3. Phenix reactor noise data

Channel No.		
1:	subassembly outlet temperature	(TATA 2018)
2:	subassembly outlet temperature	(TATA 2024)
3:	ex-core ion chamber	(Z1MR41)
4:	subassembly outlet temperature	(TATA 2119)
5:	ex-core ion chamber	(Z1MR51)
6:	pump inlet temperature	(P3MT25)
7:	primary pump flowrate	(P1MQ02)
8:	secondary pump flowrate	(S1MQ01)
9:	IHX primary inlet temperature	(P1MT01)
10:	IHX secondary inlet temperature	(S1MT01)

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS

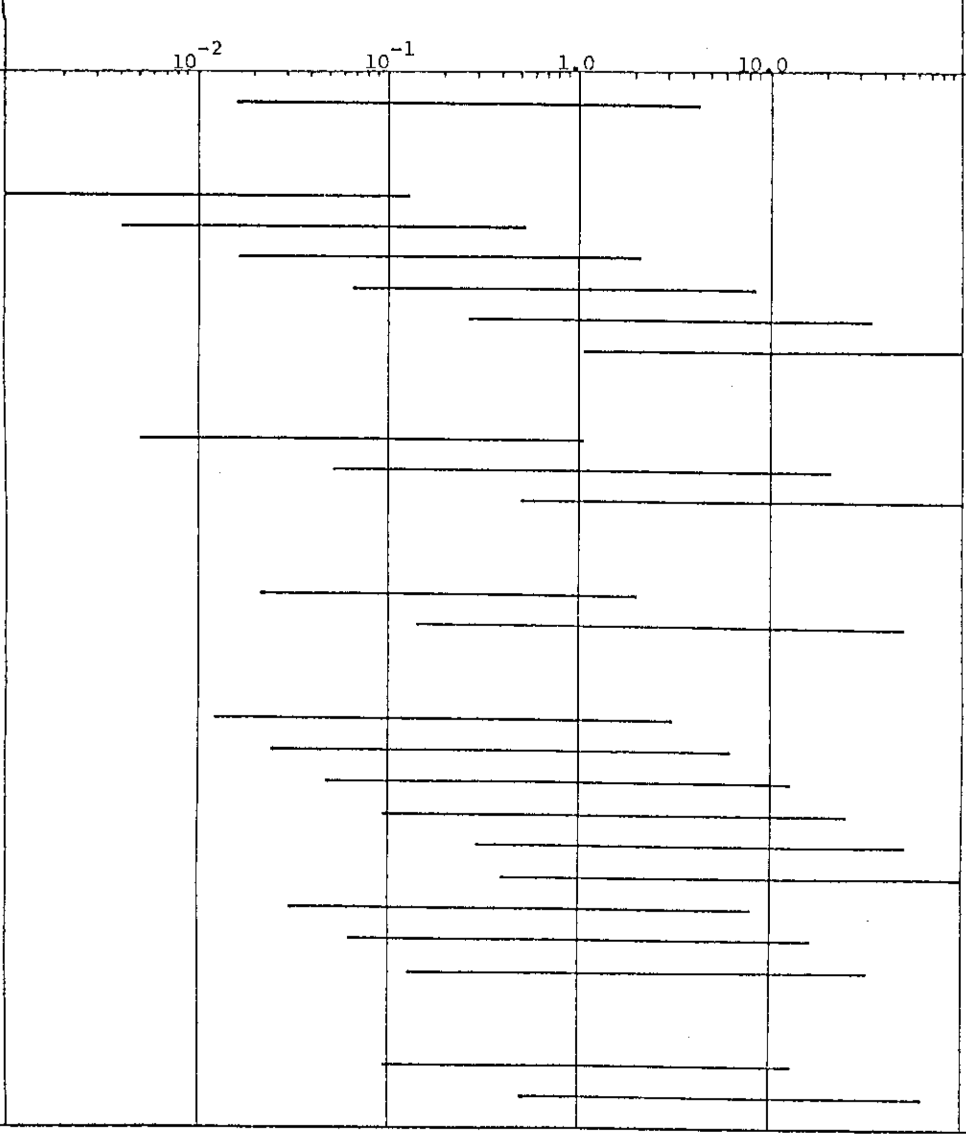
Method	(1) Pre-processing L.T.R.	(1) Pre-processing H.P.F.	I.D. Symbol	(2) System	(3) Tape No.	No. of bits for ADC	No. of Freq. Range for PSD analysis	Data	WINDOW Correlation	WINDOW P S D	WINDOW Coherence	Error Evaluation
FFT			A	S	A-9	14	2 (Phenix) 1 (others)	all	Hanning Window			Yes
			C	S	A-7	12	6	all	Cosine Tapering Window			No
			I	C2	A-14	12	3	Borssele and Phenix	Kaiser - Bessel Window			Yes
			J	S	A-6	12	1	all	Bartlett lag Window and Kaiser - Bessel Window			Yes
			K	C3	COT	12	9	all	Hanning Window			No
			L	S	A-3	11+sign	1	Artificial and Borssele	Hanning Window			No
			Q	S	A-13	12	1	all	Rectangular Window			No
			R	C3	A-15	12	3	all	Hanning Window			No
			T	S	CA-2	11+sign	1	all	-	Hanning Window	-	No
		Yes	U	S	A-5	10	2	all	Rectangular	Hanning Window		Yes
	—	Yes	D	C1	A-4	11	2	all	Uniform	Hanning Window		Yes
	Yes	—	F	S	A-2	11+sign	3	all	Cosine - Taper Data Window and Parzen Window			Yes
								Artificial Borssele Phenix	Hanning Window	(Gain) Hanning (Phase) Parzen	Parzen Window	
	—	Yes	H	S	COT	11+sign	3	all	Cosine - Taper Data Window			Yes
	—	Yes (CF)	N	C4	A-17	12	2	all	-	Hanning Window		No
	Yes	—	P	S	A-8	12	1	all	Cosine - Taper Data Window			Yes
	—	Yes (Phenix CF)	S	C3	A-1	12	1	all	Hanning Window			No
	—	Yes	W	S	A-10	14+sign	2	all	Rectangular Window			Yes
	—	Yes	X	S	A-10	14+sign	3	all	Rectangular and Hamming	Hamming Window		Yes
B-T	Yes	—	G	S	D-4	14	3	all	Parzen Window			Yes
			S	S	A-1	14	1	all	-	Hanning Window		No
A R			O	S	A-13	12	1	all				No
			S	S	A-1	14	1	all				No
			E	S	D-2	14	3	all				Yes
	—	Yes	H	S	CA-2	12	3	all				No
ARMA			B	S	A-12		1	all				No
			E	S	D-2	14	1	all				No
MEM			S	S	A-1	14	1	all				No

(1) L.T.R. ; Linear Trend Removing
H.P.F. ; High-Pass Filtering
(2) S ; Specially Organized System
Commercially available spectrum Analyzer
C1 ; OF 400 FFT Analyzer Nicolet Sci. Inst.
C2 ; SD360
C3 ; Hewlett-Packard 5420A
C4 ; [illegible]

(3) Symbols
A ; Analog tape from JAERI
D ; Digital tape from JAERI
COT ; Copied from original tape
CA-2; Copied from A-2
Number ; Identification number of test tape

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 1



I.D.	Artificial Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
A		8.0	3.75	190	6208.0	6080.0	0.0156
C		0.5		4	1024.0	2048.0	9.77E-4
		1.0		23	256.0	2944.0	3.91E-3
		4.0		96	64.0	2944.0	0.0156
		16.0		390	16.0	3120.0	0.0625
		64.0		1566	4.0	3132.0	0.250
		256.0		6266	1.0	3133.0	1.00
I		2.048		1024	400.0	1984.0	2.5E-3
		40.96		1024	400.0	1984.0	2.5E-2
		409.6		1024	400.0	1984.0	2.5E-1
J		5.6		136	45.0	6127.0	0.011
		142.9		860	7.17	6166.0	0.070
K		12.5	3.125	122	1311.0	392.0	0.0122
		25.0	6.25	275	655.4	392.0	0.0244
		50.0	12.5	369	327.7	378.0	0.0488
		100.0	25.0	369	163.8	248.0	0.0976
		200.0	50.0	369	81.92	184.0	0.195
		400.0	100.0	369	40.96	152.0	0.391
		32.0	8.0	361	512.0	392.0	0.0313
		64.0	16.0	361	256.0	392.0	0.0625
		128.0	32.0	502	128.0	261.0	0.125
L		25.0	5.0	32	10.24	327.68	0.0977
		125.0	50.0	32	2.098	65.536	0.488

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 2

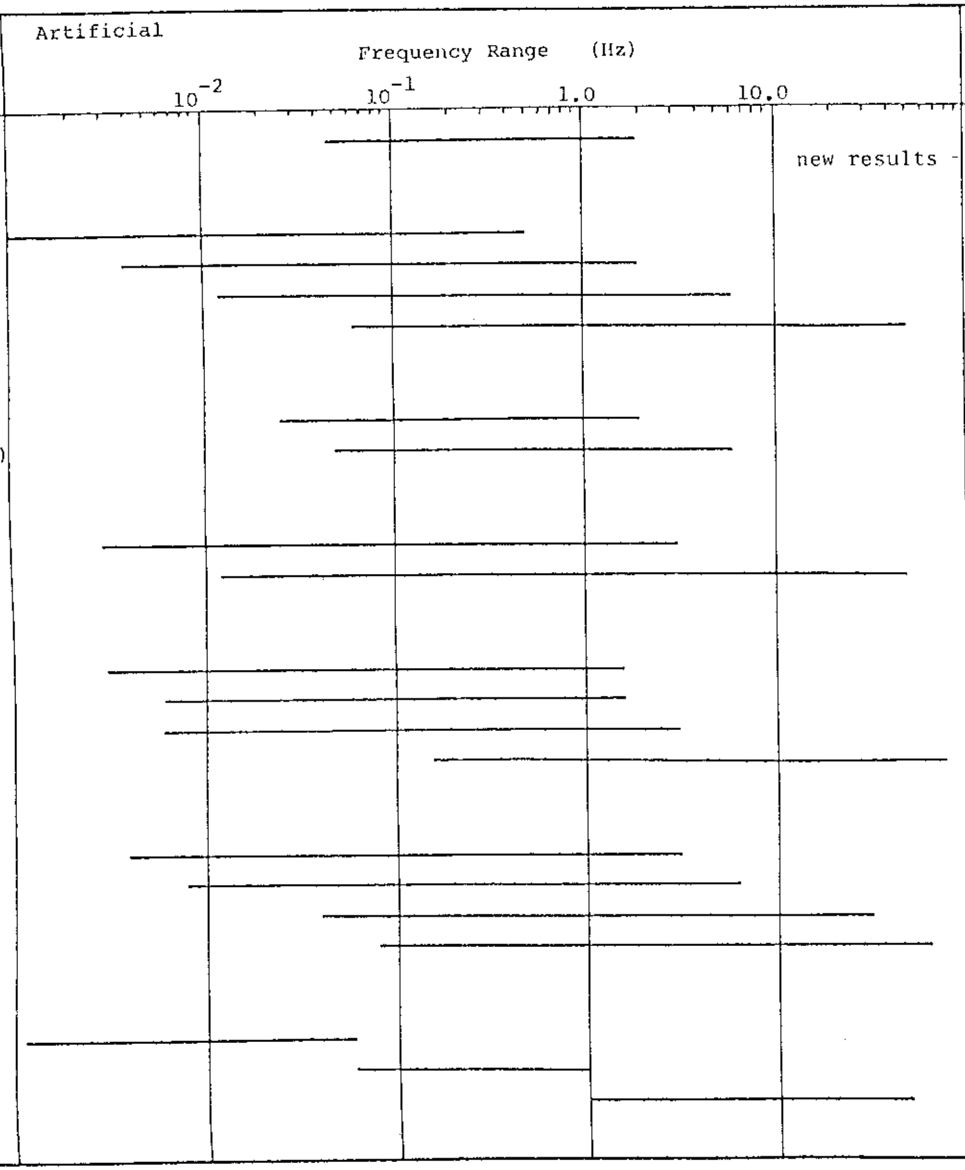
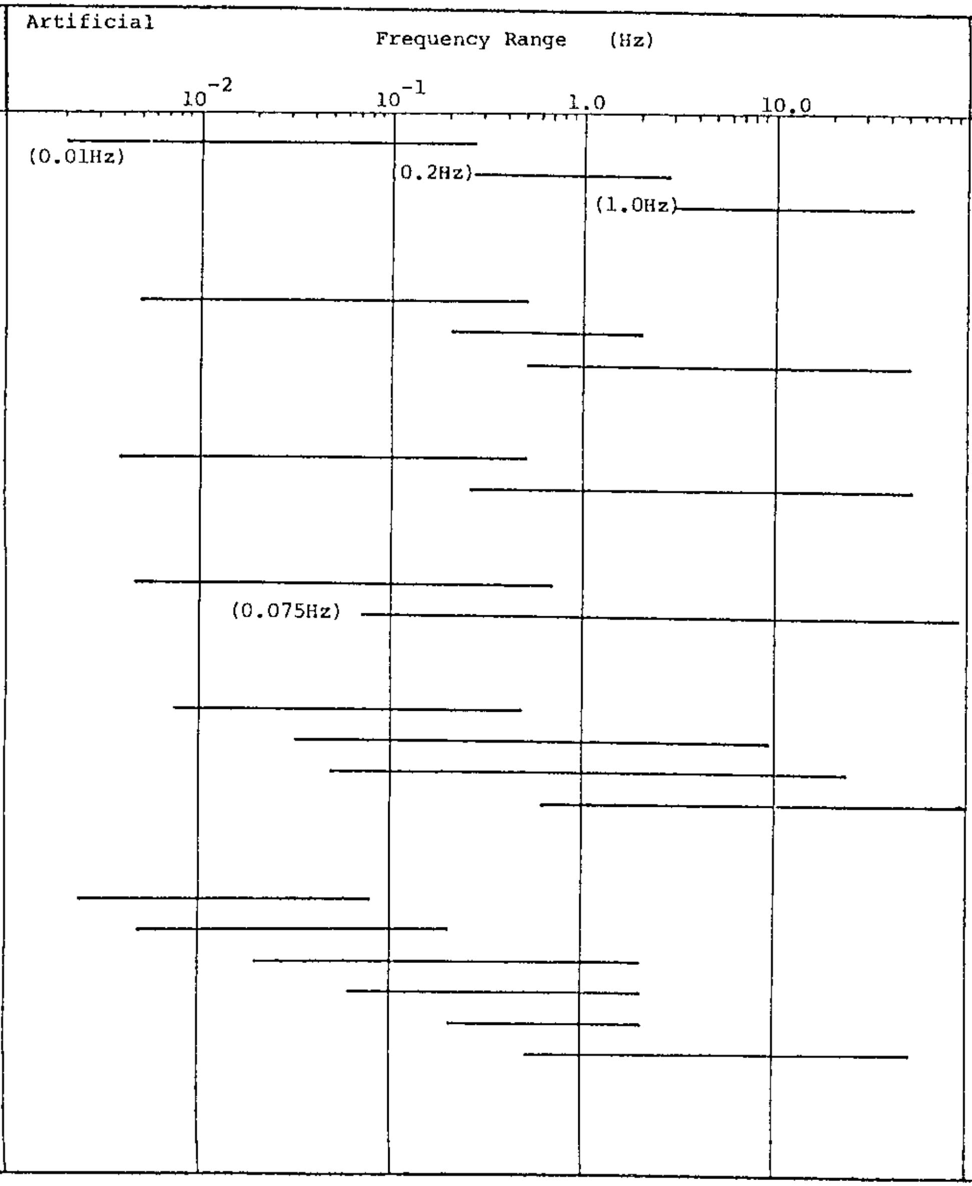
I.D.	Artificial Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
Q		25.0		1	4282.0	4282.0	0.0488
	new results →		(5.0)	(200)	(20.48)	(4096.0)	
R		2.0		84	1024.0	5888.0	9.77E-4
		8.0		150	256.0	5888.0	3.91E-3
		25.0		104	81.92	5888.0	1.22E-2
		200.0		150	10.24	5888.0	6.25E-2
S (FFT)		8.0	2.0	28	128.0	3584.0	0.0488
		25.0	6.25	40	20.48	819.2	0.0078
T		6.25	40.0	17	327.68	5570.56	0.0122
		100.0	40.0	65	81.92	5324.80	0.0031
U		3.125		18	655.4	6226.0	0.0015
		3.125		73	327.7	6226.0	0.0030
		6.25		73	327.7	6226.0	0.0030
		156.25		455	13.11	1501.0	0.0760
D		8.0	3.125	16	256.0	4096.0	3.9E-3
		16.0	6.25	32	128.0	4096.0	7.8E-3
		80.0	31.25	128	25.6	3276.0	3.9E-2
		260.0	62.5	256	12.8	3276.0	7.8E-2
F		1.25	2.5	7	819.2	5734.4	1.22E-3
		10.0	8.0	60	102.4	6144.0	9.77E-3
		100.0	80.0	100	10.24	1024.0	9.77E-2

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 3



I.D.	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
H	8.33	4.0	21	246.0	5161.0	4.07E-3
	20.0	10.0	45	25.6	1152.0	3.91E-2
	100.0	50.0	45	1.28	576.0	7.81E-1
N	10.24		256	200.0	5000.0	0.005
	10.24		256	200.0	5000.0	0.005
	10.24		256	20.0	5120.0	0.05
P	16.0	7.8	24	1024.0	6144.0	3.91E-3
	128.0	7.8	192	128.0	768.0	0.25
W	2.6	0.75	18	196.6	3539.0	5.09E-3
	195.3	52.0	344	10.5	3608.0	9.54E-2
X	33.3	12.0	23	245.8	5653.0	0.008
	20.0	10.0	100	51.2	5120.0	0.034
	100.0	40.0	100	20.5	2048.0	0.052
	1250.0	500.0	100	1.638	164.0	0.65
G	100.0		1	1650.0	1650.0	0.0025
	100.0		1	1650.0	1650.0	0.002
	100.0		1	1650.0	1650.0	0.02
	100.0		1	1650.0	1650.0	0.02
	100.0		1	1650.0	1650.0	0.04
	100.0		1	1650.0	1650.0	0.50

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 4

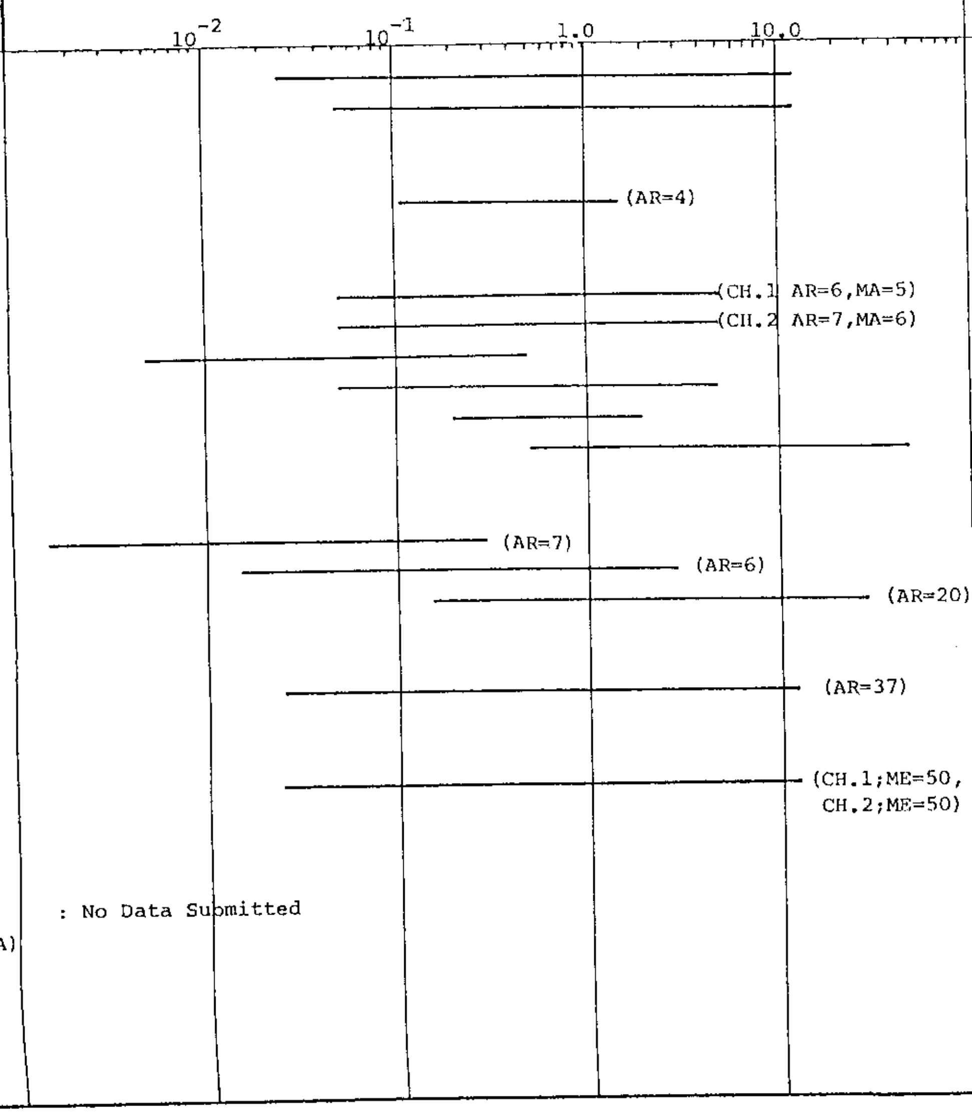
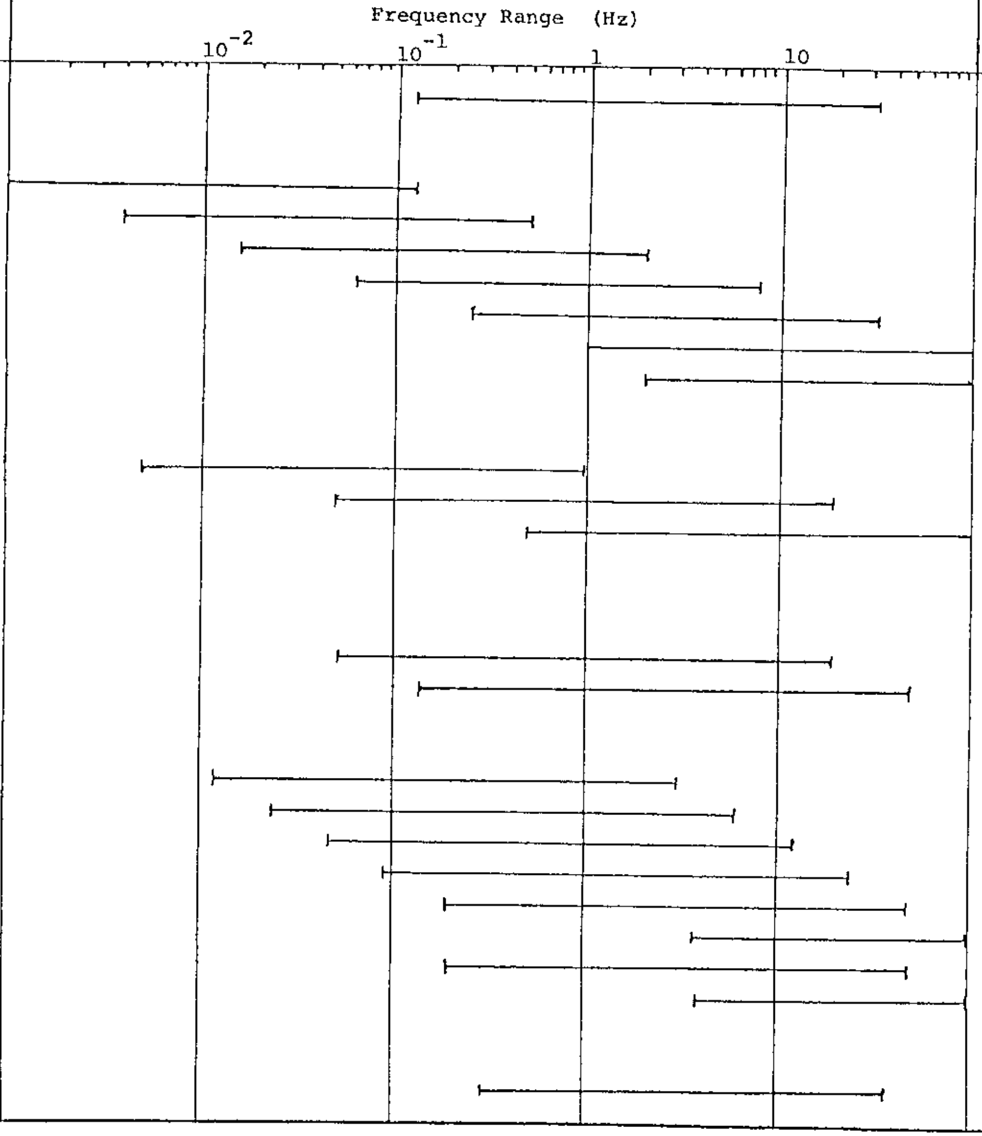
I.D.	Artificial Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
							
S (BT)		25.0	8.0	1	160.0	160.0	0.025
		25.0	8.0	1	160.0	160.0	0.05
O	(AR=4)	3.125	1.0	1	3932.0	3932.0	-
E	(CH.1 AR=6,MA=5)	100.0		1	100.0	100.0	0.05
	(CH.2 AR=7,MA=6)	100.0		1	100.0	100.0	0.05
		100.0		1	100.0	100.0	0.005
		100.0		1	100.0	100.0	0.05
		100.0		1	100.0	100.0	0.05
		100.0		1	100.0	100.0	0.5
M	(AR=7)	0.625	5.12	1	3276.8	3276.8	0.0015
	(AR=6)	6.25	5.12	3	327.68	983.04	0.015
	(AR=20)	62.5	5.12	3	32.768	98.304	0.15
S (AR)	(AR=37)	25.0	8.0	1	160.0	160.0	0.025
S (ME)	(CH.1;ME=50, CH.2;ME=50)	25.0	8.0	1	80.0	80.0	0.025
B (ARMA)	: No Data Submitted						

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

Borssele

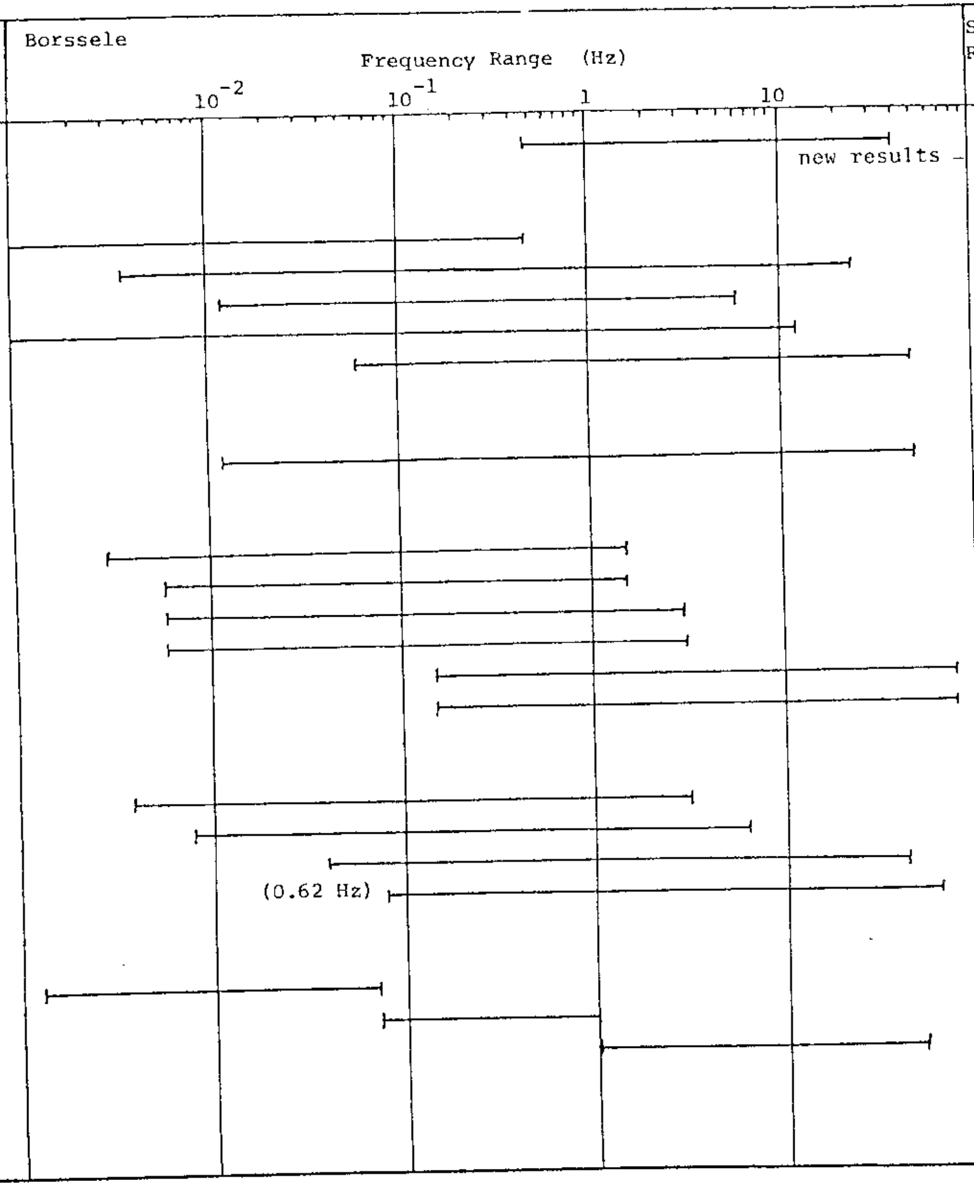


No.5

I.D.	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
A	64.0	25.0	1550	6259.0	6200.0	0.125
C	0.5	-	4	1024.0	2048.0	9.77E-4
	1.0	-	23	256.0	2944.0	3.91E-3
	4.0	-	96	64.0	2944.0	1.56E-2
	16.0	-	388	16.0	3104.0	6.25E-2
	64.0	-	1559	4.0	3118.0	0.25
	256.0	110.0	6240	1.0	3120.0	1.0
	1024.0	400.0	12480	0.5	3120.0	2.0
I	2.048	-	1024	400.0	1984.0	2.5E-3
	40.96	-	1024	400.0	1984.0	2.5E-2
	409.6	-	1024	400.0	1984.0	2.5E-1
J	142.9	-	860	7.17	6166.0	0.070
	55.5	-	330	18.4	6082.0	0.027
K	12.50	3.125	115	1311.0	373.0	1.22E-2
	25.0	6.25	264	655.4	377.0	2.45E-2
	50.0	12.5	369	327.7	374.0	4.88E-2
	100.0	25.0	369	163.8	249.0	9.77E-2
	200.0	50.0	369	81.92	188.0	1.95E-1
	400.0	100.0	369	40.96	153.0	3.90E-1
	200.0	50.0	786	81.92	383.0	1.95E-1
	400.0	100.0	786	40.96	319.0	3.91E-1
L	76.9	31.5	64	3.33	213.0	0.3005

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

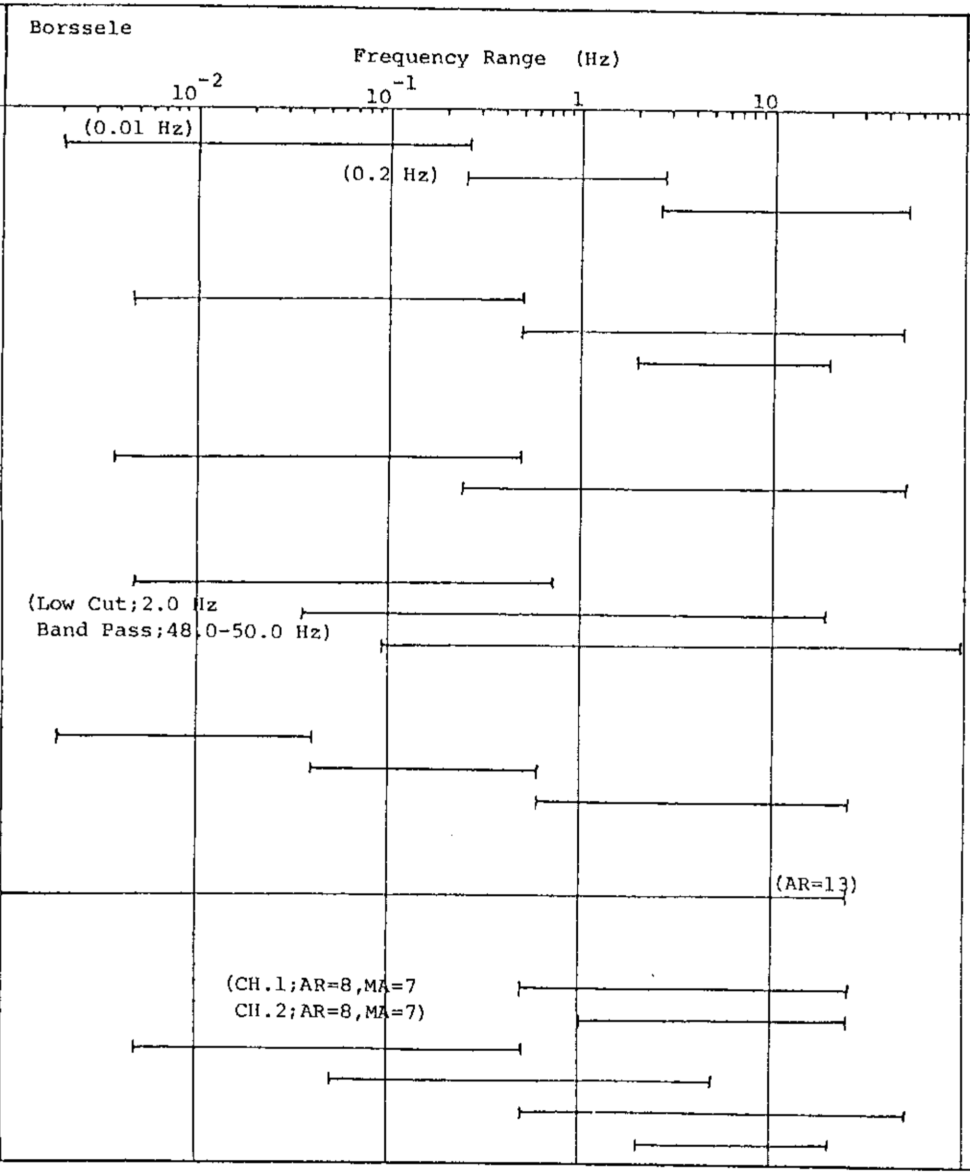
No. 6



I.D	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
Q	250.0	- (80.0)	1 (300)	768.0 (2.048)	768.0 (614.4)	0.4883
R	2.0	-	80	1024.0	5888.0	9.77E-4
	100.0	-	111	20.48	6304.0	3.90E-4
	25.0	-	125	81.92	5888.0	1.22E-2
	50.0	-	117	40.96	6304.0	-
	200.0	-	125	10.24	6304.0	6.25E-2
T	100.0	40.0	65	81.92	5324.8	1.22E-2
U	3.125	-	18	655.4	6226.0	1.53E-3
	3.125	-	73	327.7	6226.0	3.00E-3
	6.25	-	73	327.7	6226.0	3.00E-3
	6.25	-	37	327.7	6226.0	3.00E-3
	156.25	-	455	13.11	1501.0	7.60E-2
	156.25	-	228	13.11	1501.0	7.60E-2
D	8.0	3.125	16	256.0	4096.0	3.90E-3
	16.0	6.25	32	128.0	4096.0	7.80E-3
	80.0	31.25	128	25.6	3276.0	3.90E-2
	260.0	62.5	256	12.8	3276.0	7.80E-2
F	1.25	2.5	7	819.2	5734.4	1.22E-3
	10.0	8.0	60	102.4	6144.0	9.77E-3
	100.0	80.0	100	10.24	1024.0	9.77E-2

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

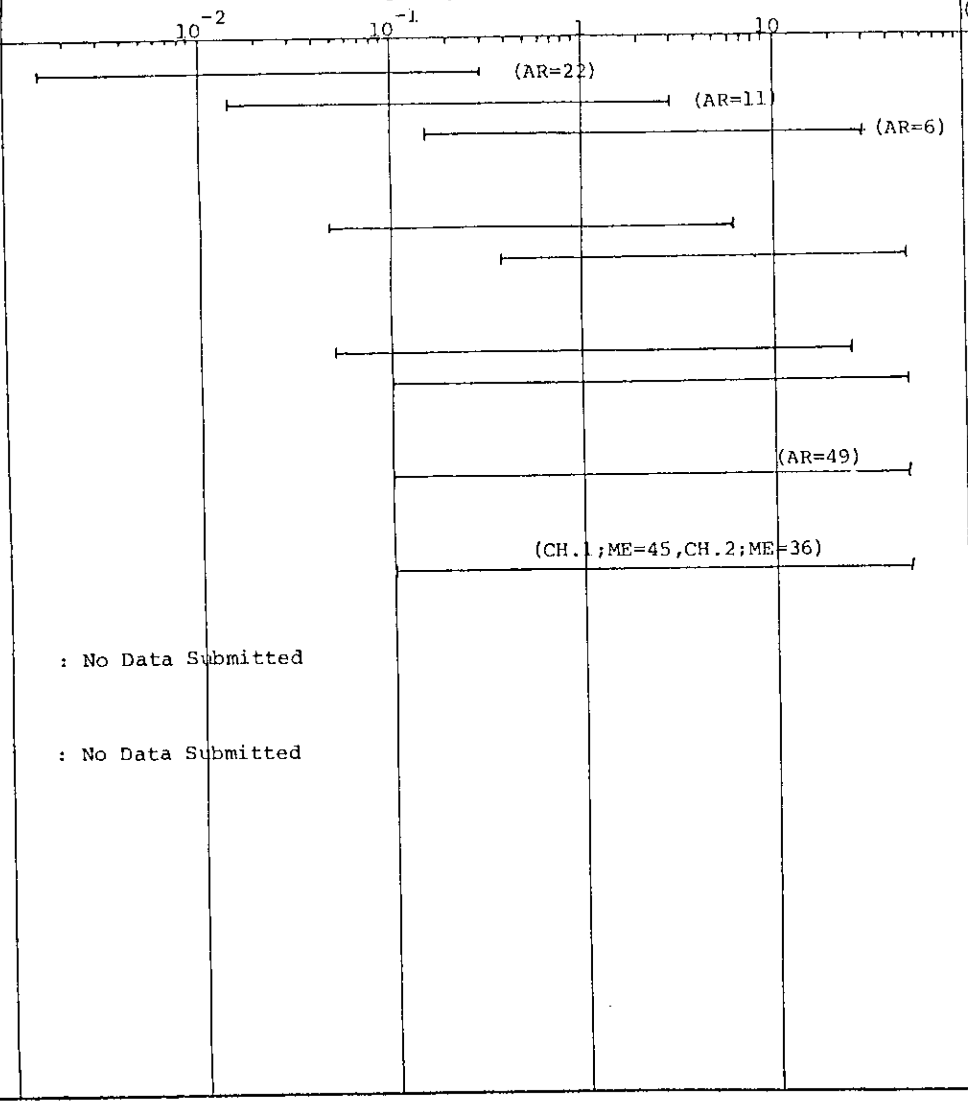
No. 7



I.D.	Sampling Rate (1/sec)	Coner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
H	8.33	4.0	21	246.0	5161.0	4.07E-3
	20.0	10.0	45	25.6	1152.0	3.91E-2
	100.0	50.0	45	1.28	57.6	7.81E-1
N	10.24	-	256	200.0	5000.0	0.005
	102.4	-	256	20.0	5120.0	0.050
	204.8	-	512	20.0	5000.0	0.050
P	16.0	7.8	24	1024.0	6144.0	3.91E-3
	128.0	7.8	192	128.0	768.0	2.50E-1
W	2.6	0.75	13	196.6	2556.0	5.09E-3
	195.3	-	249	10.5	2511.0	9.54E-2
	39.7	20.0	100	26.27	2621.0	3.80E-2
G	100.0	-	1	1650.0	1650.0	0.002
	100.0	-	1	1650.0	1650.0	0.02
	100.0	-	1	1650.0	1650.0	0.05
O	50.0	16.0	1	614.0	614.0	-
E	100.0	-	1	100.0	100.0	0.25
	100.0	-	1	100.0	100.0	0.25
	100.0	-	1	100.0	100.0	0.005
	100.0	-	1	100.0	100.0	0.05
	100.0	-	1	100.0	100.0	0.50
	100.0	-	1	100.0	100.0	0.50

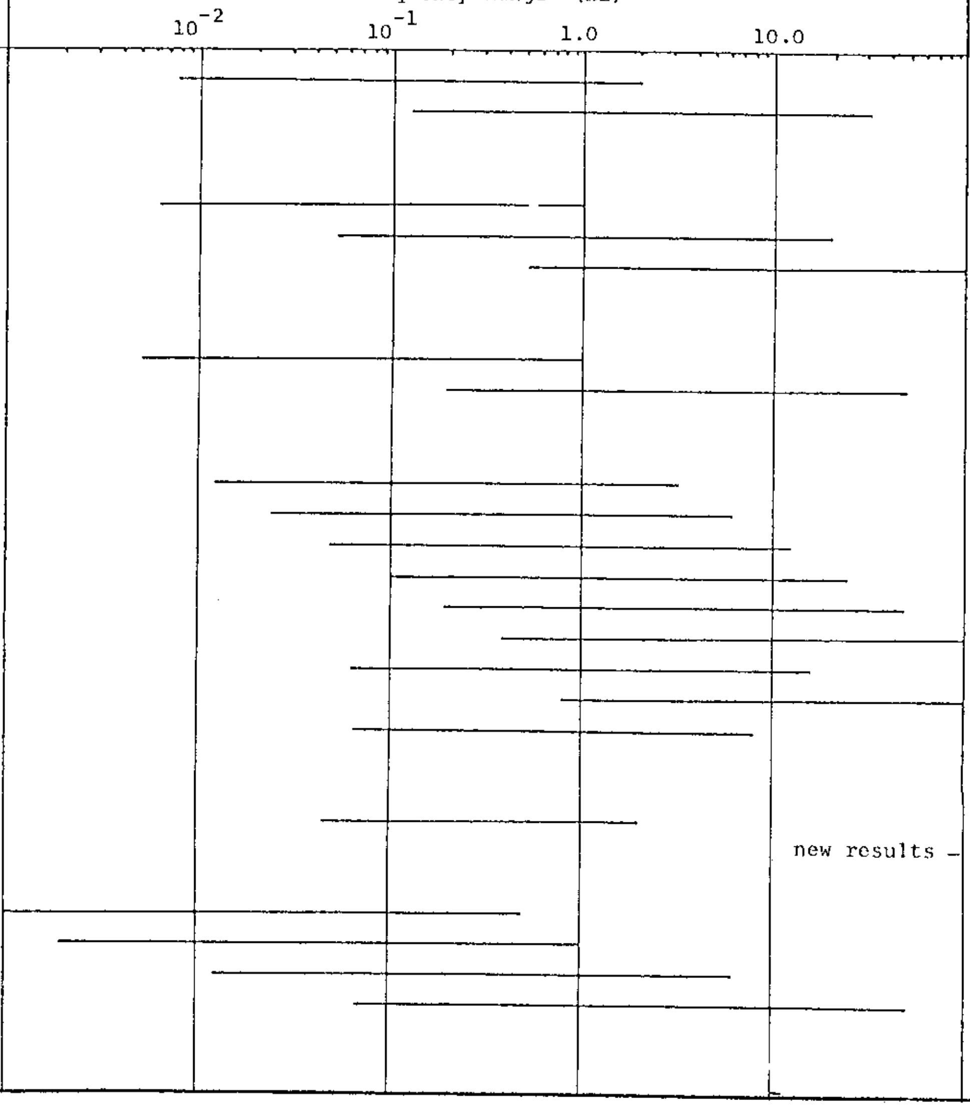
TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 8



I.D.	Borssele Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resolu. (Hz)
M	(AR=22)	0.625	-	1	3276.8	3276.8	0.0015
	(AR=11)	6.25	-	3	327.68	983.04	0.015
	(AR=6)	62.5	-	3	32.768	98.304	0.150
S (FFT)		25.0	6.25	40	20.48	819.2	4.88E-2
		200.0	50.0	28	5.12	143.36	1.95E-1
S (BT)		50.0	16.0	1	80.0	80.0	0.05
		100.0	-	1	40.0	40.0	0.10
S (AR)	(AR=49)	100.0	-	1	40.0	40.0	0.10
S (ME)	(CH.1;ME=45,CH.2;ME=36)	100.0	-	1	20.0	20.0	0.10
B (ARMA)	: No Data Submitted						
X (FFT)	: No Data Submitted						

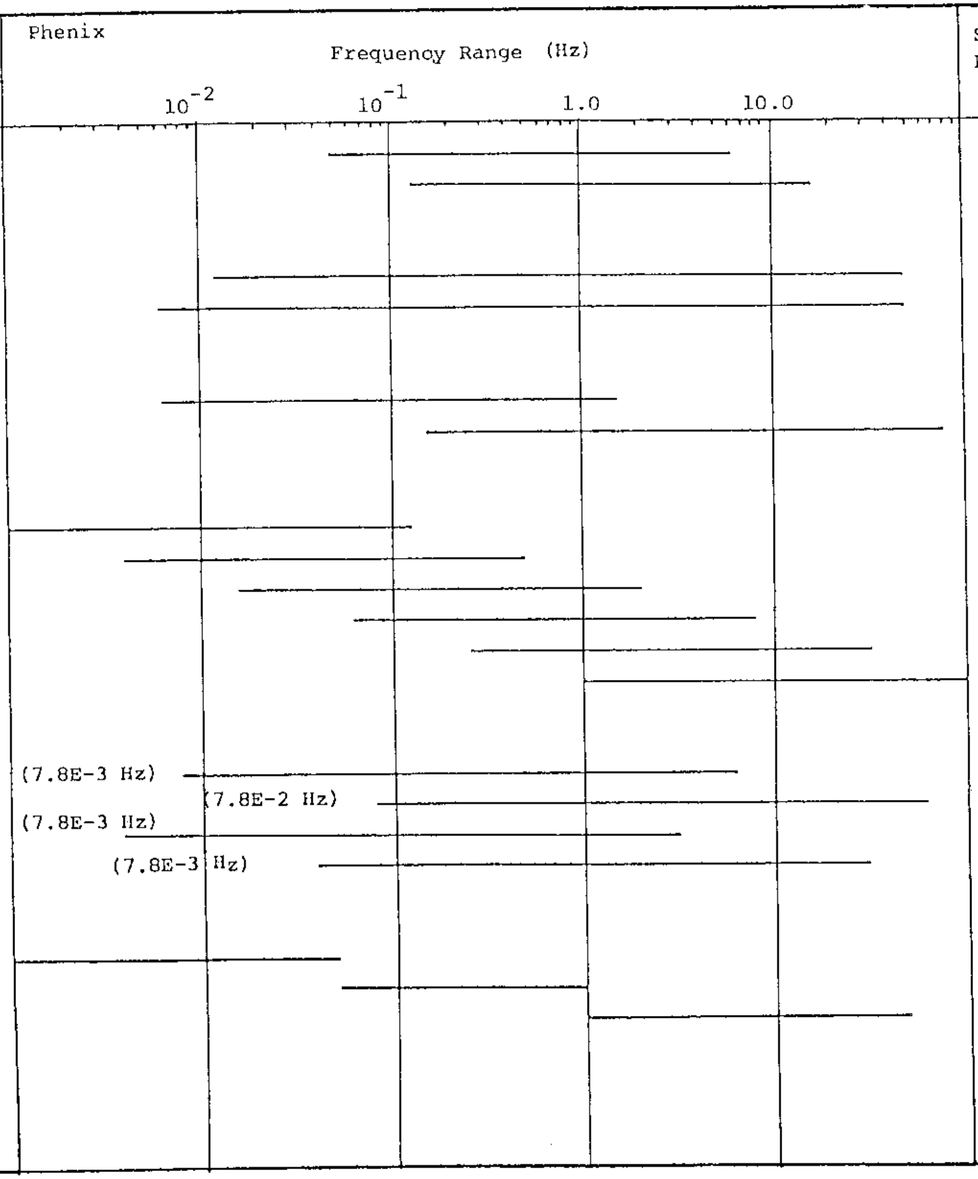
TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)



I.D.	Phenix Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	NO. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
A		4.0 64.0	1.875 25.0	87 1587	6348.0 6348.0	5568.0 6348.0	0.00781 0.1250
I		2.048 40.96 409.6		1024 1024 1024	400.0 400.0 400.0	1984.0 1984.0 1984.0	2.5E-3 2.5E-2 2.5E-1
J		2.8 142.9		34 860	180.2 7.17	6127.0 6166.0	0.0028 0.070
K		12.5 25.0 50.0 100.0 200.0 400.0 64.0 400.0 32.0	3.125 6.25 12.5 25.0 50.0 100.0 16.0 100.0 8.0	120 270 369 369 369 369 496 450 320	1311.0 655.4 327.7 163.8 81.92 40.96 256.0 20.48 256.0	385.0 385.0 376.0 248.0 184.0 152.0 388.0 387.0 256.0	0.0122 0.0244 0.0488 0.0977 0.1953 0.3906 0.0625 0.7813 0.0625
Q	new results	25.0	(5.0)	1 (200)	4282.0 (20.48)	4282.0 (4096.0)	0.0488
R		2.0 4.0 25.0 200.0		80 100 125 125	1024.0 512.0 81.92 10.24	3648.0 3232.0 3712.0 4160.0	9.77E-4 1.95E-3 1.22E-2 6.25E-2

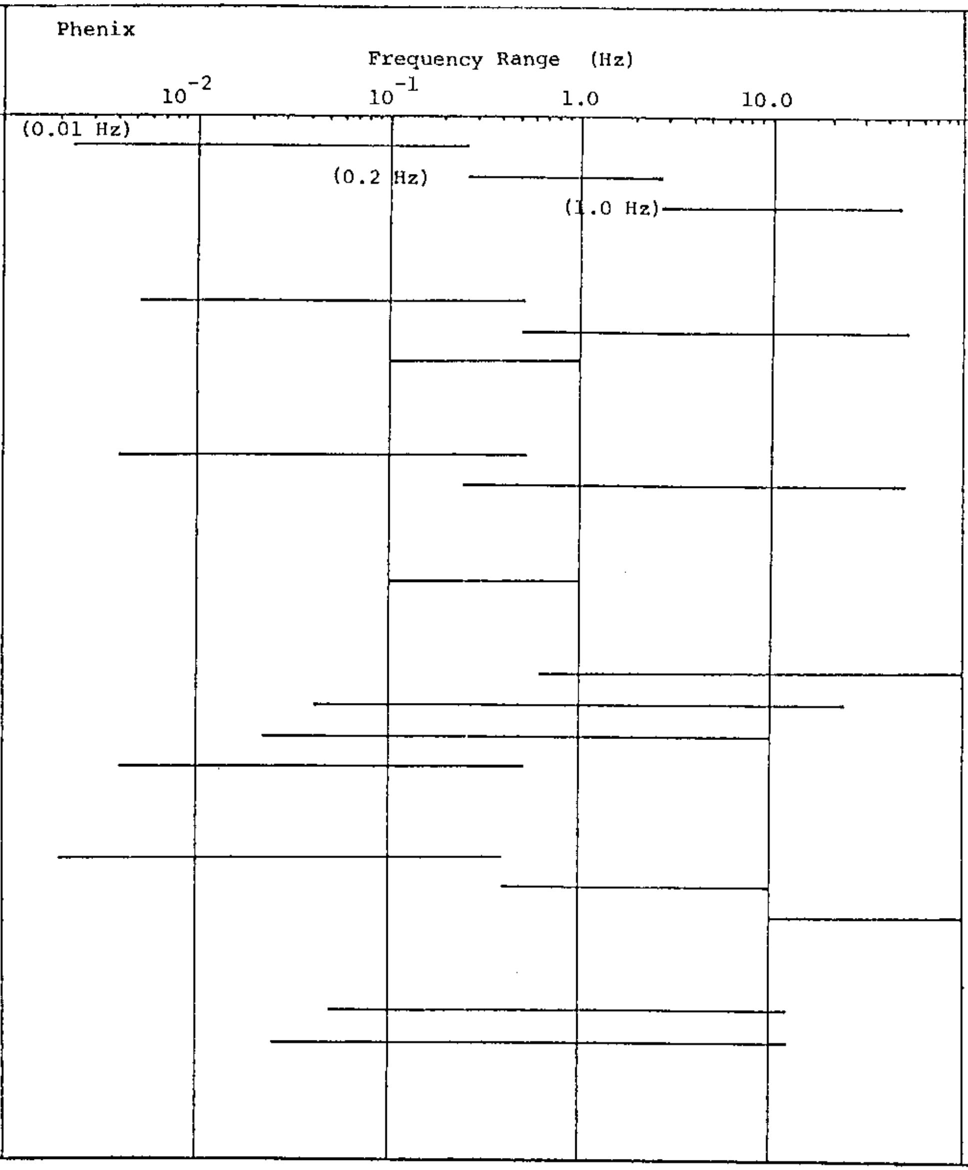
TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 10



I.D.	Phenix Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Anarysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
S (FFT)		25.0	12.5	40	20.48	819.2	0.0488
		64.0	32.0	28	16.0	448.0	0.0625
T		100.0	40.0	65	81.92	5342.8	0.0122
		100.0	40.0	30	163.84	4915.2	0.0061
U		3.125		73	327.7	6226.0	0.0030
		156.25		455	13.11	1501.0	0.0760
C		0.25		4	1024.0	2048.0	9.77E-4
		1.0		21	256.0	2688.0	3.91E-3
		4.0		88	64.0	2816.0	0.0156
		16.0		358	16.0	2864.0	0.0625
		64.0		1439	4.0	2878.0	0.2500
		256.0	110.0	5762	1.0	2881.0	1.00
D	(7.8E-3 Hz)	16.0	6.25	32	128.0	4096.0	7.8E-3
	(7.8E-2 Hz)	260.0	62.5	256	12.8	3276.0	7.8E-2
	(7.8E-3 Hz)	8.0	3.125	16	256.0	4096.0	3.9E-3
	(7.8E-3 Hz)	80.0	31.25	128	25.6	3276.0	3.9E-2
F		1.25	2.5	7	819.2	5734.4	1.22E-3
		10.0	8.0	60	102.4	6144.0	9.77E-3
		100.0	80.0	100	10.24	1024.0	9.77E-2

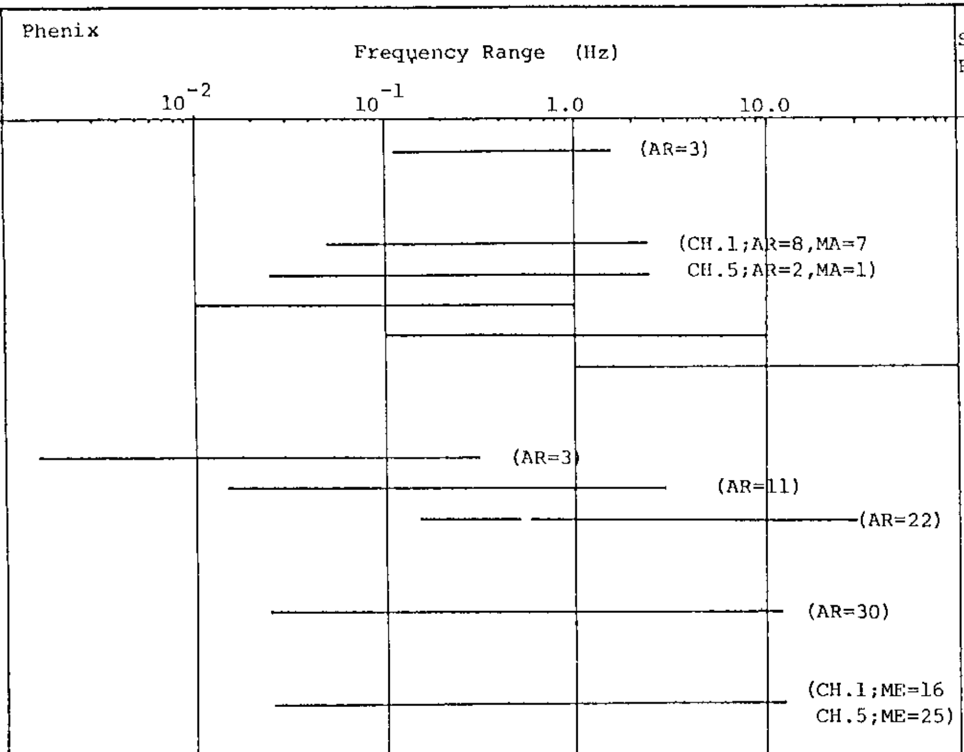
TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)



I.D.	Samplig Rate (1/sec)	Coner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
H	8.33	4.0	21	2.46	5734.4	4.07E-3
	20.0	10.0	45	25.6	1152.0	3.91E-2
	100.0	50.0	45	1.28	57.6	7.81E-1
N	10.24		256	200.0	5000.0	0.005
	102.4		256	20.0	5120.0	0.050
	10.24		512	200.0	5000.0	0.005
P	16.0	7.8	24	1024.0	6144.0	3.906E-3
	128.0	61.0	192	28.0	768.0	0.250
W	2.44	1.0	26	104.9	2726.0	9.53E-3
X	1250.0	500.0	100	1.638	16.4	0.650
	100.0	40.0	100	20.5	2048.0	0.052
	40.0	15.0	100	51.2	5120.0	0.034
	33.3	12.0	23	254.8	5653.0	0.004
G	200.0		1	825.0	825.0	0.002
	200.0		1	825.0	825.0	0.10
	200.0		1	825.0	825.0	1.00
S (BT)	25.0	8.0	1	160.0	160.0	0.05
	25.0	8.0	1	160.0	160.0	0.025

TABLE 2. SUMMARY OF METHODS OF DATA ANALYSIS (CONTINUED)

No. 12



I.D.	Phenix Frequency Range (Hz)	Sampling Rate (1/sec)	Corner Freq. (Hz)	No. of Average	Data Length for an Analysis	Total Length Analyzed (sec)	Freq. Resol. (Hz)
O	(AR=3)	3.125	1.0	1	160.0	160.0	0.025
E	(CH.1;AR=8,MA=7	200.0		1	50.0	50.0	0.025
	CH.5;AR=2,MA=1)	200.0		1	50.0	50.0	0.025
		200.0		1	50.0	50.0	0.01
		200.0		1	50.0	50.0	0.10
		200.0		1	50.0	50.0	1.00
M	(AR=3)	0.625	5.12	1	3276.8	3276.8	0.0015
	(AR=11)	6.250	5.12	3	327.68	327.68	0.015
	(AR=22)	62.50	5.12	3	32.768	32.768	0.150
S (AR)	(AR=30)	25.0	8.0	1	160.0	160.0	0.025
S (ME)	(CH.1;ME=16 CH.5;ME=25)	25.0	8.0	1	80.0	80.0	0.025
B (ARMA)	: No Data Submitted						
L (FFT)	: No Data Submitted						

TABLE 3. ESTIMATES OF STANDARD DEVIATION

Method	Pre-Processing (Yes or No)	I.D. Symbol	Artificial Noise		Borssele Noise		Phenix Noise	
			Ch. 1	Ch. 2	Ch. 1	Ch. 2	Ch. 1	Ch.5
FFT	No	A	0.227v (upto 4Hz)	0.272v (upto 4Hz)	0.385v (upto 32Hz)	0.405 v (upto 32Hz)	0.057v (upto 2Hz) 0.079v (upto 32Hz)	0.194v (upto 2Hz) 0.334v (upto 32Hz)
		C	0.235v	0.273v	0.39v	0.407v	0.0764v	0.824v
		I			0.394v	0.394v	0.050v	0.044v
		J	0.243v (0.14~50Hz) 0.236v (0.022~2Hz)	0.105v (0.14~50Hz) 0.211v (0.022~2Hz)	0.421v (0.14~50Hz) 0.420v (0.06~20Hz)	0.423v (0.14~50Hz) 0.425v (0.06~20Hz)	0.022v (0.14~50Hz) 0.056v (0.006~1Hz)	0.209v (0.14~50Hz) 0.236v (0.006~1Hz)
		K	0.2283 ($5*10^{-3}$~50Hz) 0.04845 (0.2~2Hz)	0.200 ($5*10^{-3}$~50Hz) 0.006238 (0.2~2Hz)	0.001671 ($5*10^{-3}$~50Hz) 0.00009230 (2~20Hz)	0.002402 ($5*10^{-3}$~50Hz) 0.0002038 (2~20Hz)	0.0003366 ($5*10^{-3}$~50Hz) 0.00002205 (0.1~1Hz)	0.005157 ($5*10^{-3}$~50Hz) 0.0003410 (0.1~1Hz)
		L	0.247v (0-50Hz)	0.188v (0-50Hz)	0.379v (0-31.5Hz)	0.437v (0-31.5Hz)	————	————
		Q	0.22v	0.15v	0.12 %	0.20 %	0.020 %	0.32 %
		R	$1.69*10^{-1}$	$1.75*10^{-1}$	$1.02*10^{-2}$	$2.34*10^{-3}$	$6.26*10^{-4}$	$4.43*10^{-3}$
		T	0.2367v	0.2720v	0.5363v	0.5367v	0.0535v	0.2467v
	Yes	U	0.215v (0.114~78.1Hz) 0.218v (0.0046~3.12Hz)	4.73E-2v (0.114~78.1Hz) 0.198v (0.0046~3.12Hz)	0.156 % (0.114~78.1Hz) 0.169 % (0.0046~3.12Hz)	0.224 % (0.114~78.1Hz) 0.230 % (0.0046~3.12Hz)	0.0123 % (0.114~78.1Hz) 0.0388 % (0.0023~1.56Hz)	0.412 % (0.114~78.1Hz) 0.441 % (0.0023~1.56Hz)
		D	0.22v	0.22v	0.41v	0.42v	0.035v	0.21v
		F	0.240v	0.284v	0.456v	0.448v	0.0542v	0.302v
		H	0.38v	0.26v	0.61v	0.53v	0.056v	0.39v
		N	0.254	0.283	0.420	0.425	0.057	0.260
		P	0.243	0.098	3.418	0.342	0.34	0.141
		W	0.2383v	0.128v	0.305v	0.486v	0.0191v	0.159v
		X	0.23v	0.28v	0.45v	0.42v	0.15v	0.25v
B-T	Yes	G	0.0277v	0.0375v	0.0473v	0.0529v	0.000531v	0.0321v
A R	No	O	0.20v	0.25v	0.170 %	0.230 %	0.034 %	0.392 %
		E	0.0836731 (Data size:10000)	0.1216223 (Data size:10000)	0.1422462	0.1590943	4.0169329	0.0966959
	Yes	M	0.194v (1.6sec) 0.236v (0.16sec) 0.223v (0.016sec)	0.281v (1.6sec) 0.209v (0.16sec) 0.0958v (0.016sec)	0.375v (1.6sec) 0.423v (0.16sec) 0.374v (0.016sec)	0.341v (1.6sec) 0.414v (0.16sec) 0.367v (0.016sec)	0.0433v (1.6sec) 0.0392v (0.16sec) 0.0147v (0.016sec)	0.189v (1.6sec) 0.195v (0.16sec) 0.202v (0.016sec)
ARMA	No	B	2.218	1.694	1.906	2.118	1.079	2.885
FFT, B-T AR, MEM		S	0.275V (0-8Hz)	0.365v (0-8Hz)	0.326v	0.381v	0.0375v (0-8Hz)	0.191v (0-8Hz)

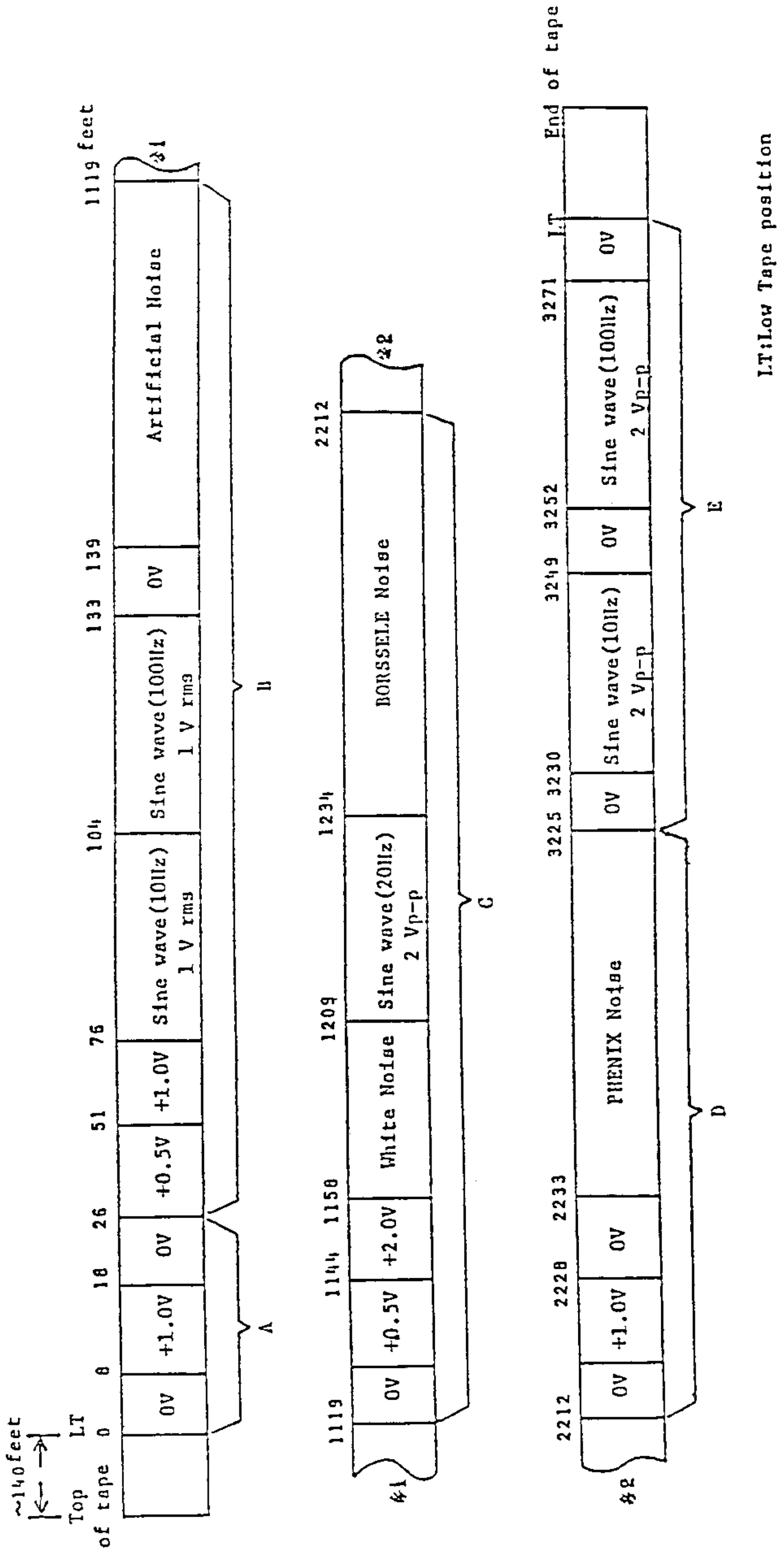


Fig. 1 Order of signal recording in the data tape

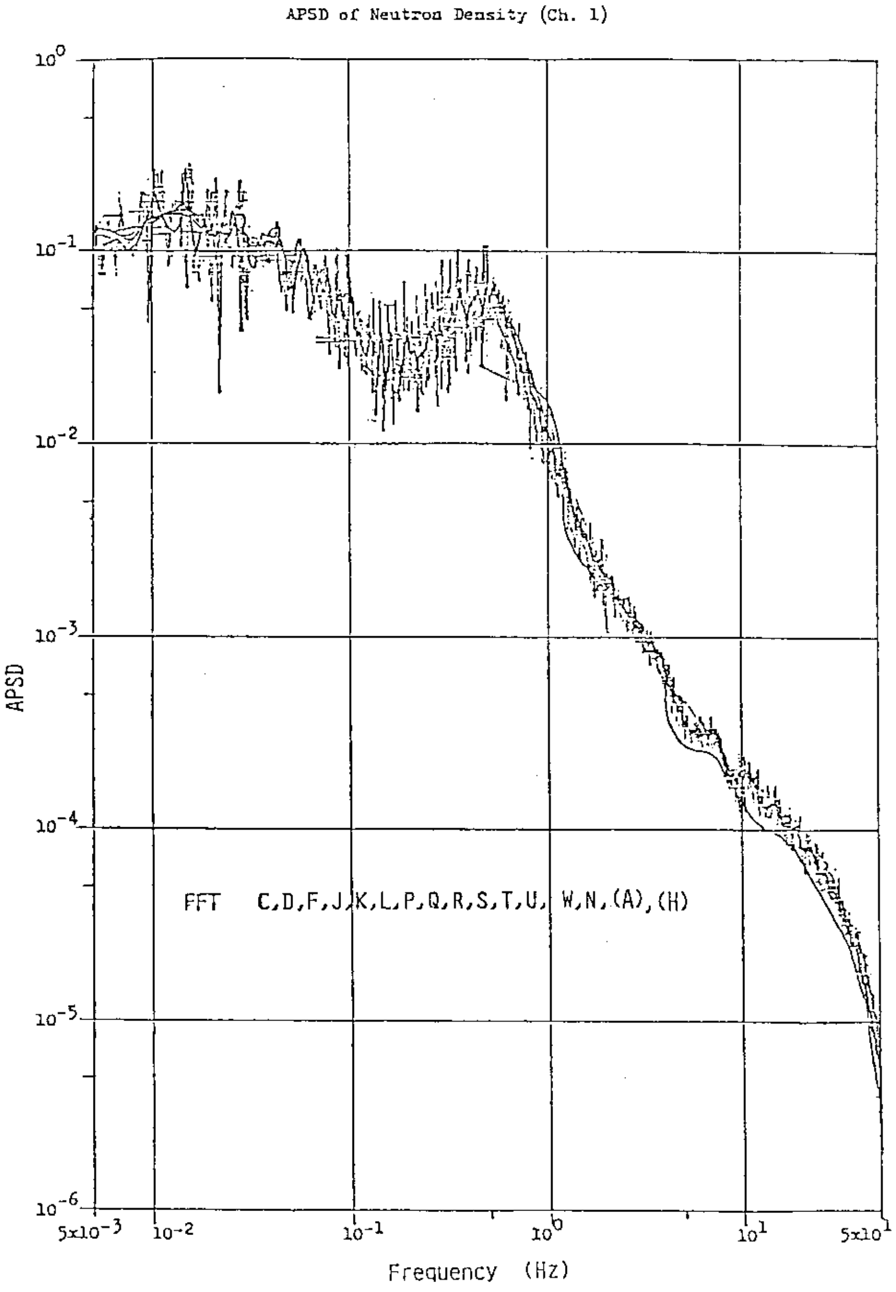

APSD of Neutron Density (Ch. 1)
APSD
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
FFT C,D,F,J,K,L,P,Q,R,S,T,U,W,N,(A),(H)
5×10^{-3}
10^{-2}
10^{-1}
10^0
10^1
5×10^1
Frequency (Hz)

Fig. 2-1

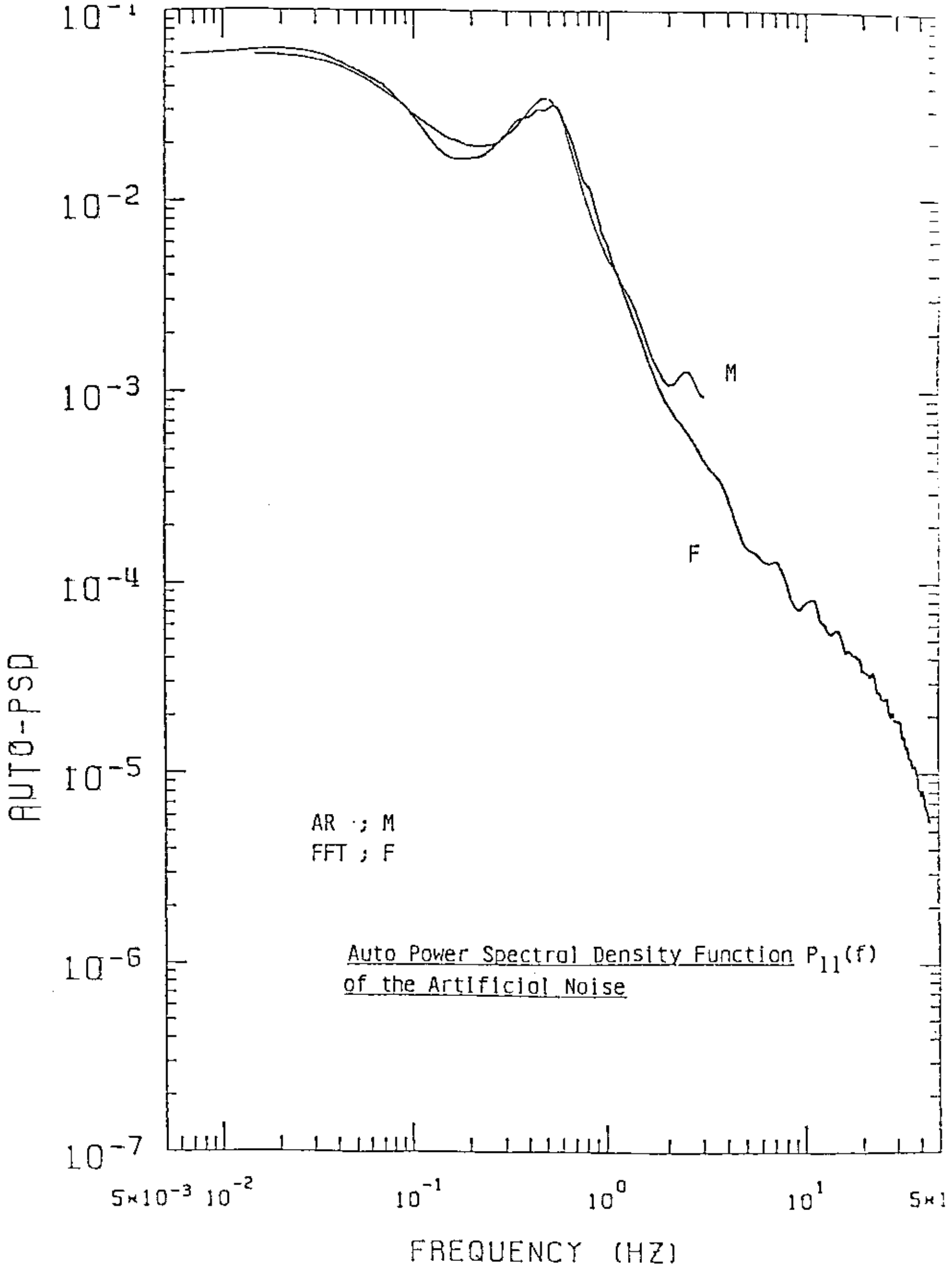

AUTO-PSD
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
M
F
AR ; M
FFT ; F
Auto Power Spectral Density Function $P_{11}(f)$
of the Artificial Noise
5×10^{-3}
10^{-2}
10^{-1}
10^0
10^1
5×1
FREQUENCY (HZ)

Fig. 2-2

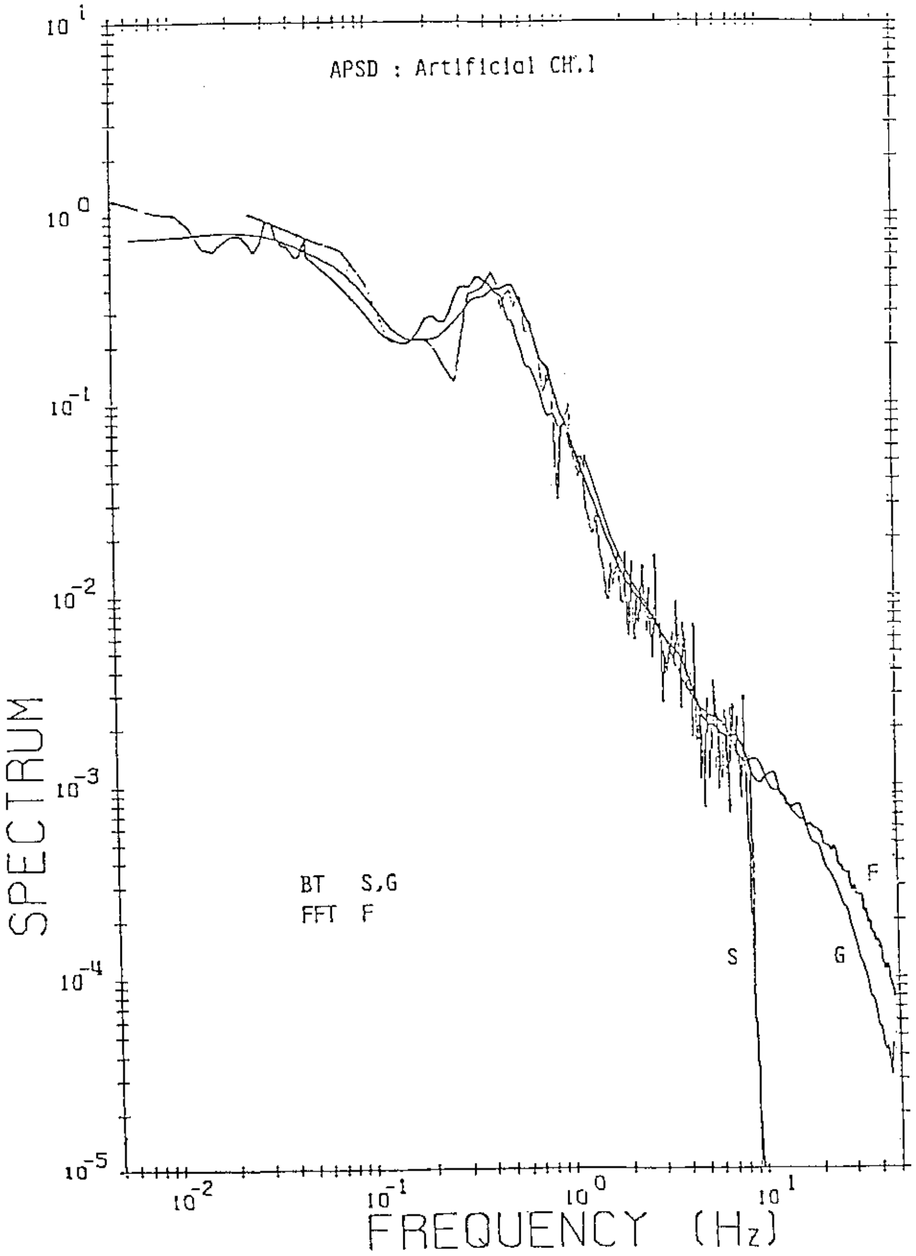

APSD : Artificial CH.1
SPECTRUM
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-2
10^-1
10^0
10^1
FREQUENCY (Hz)
BT S,G
FFT F
S
G
F

Fig. 2-3

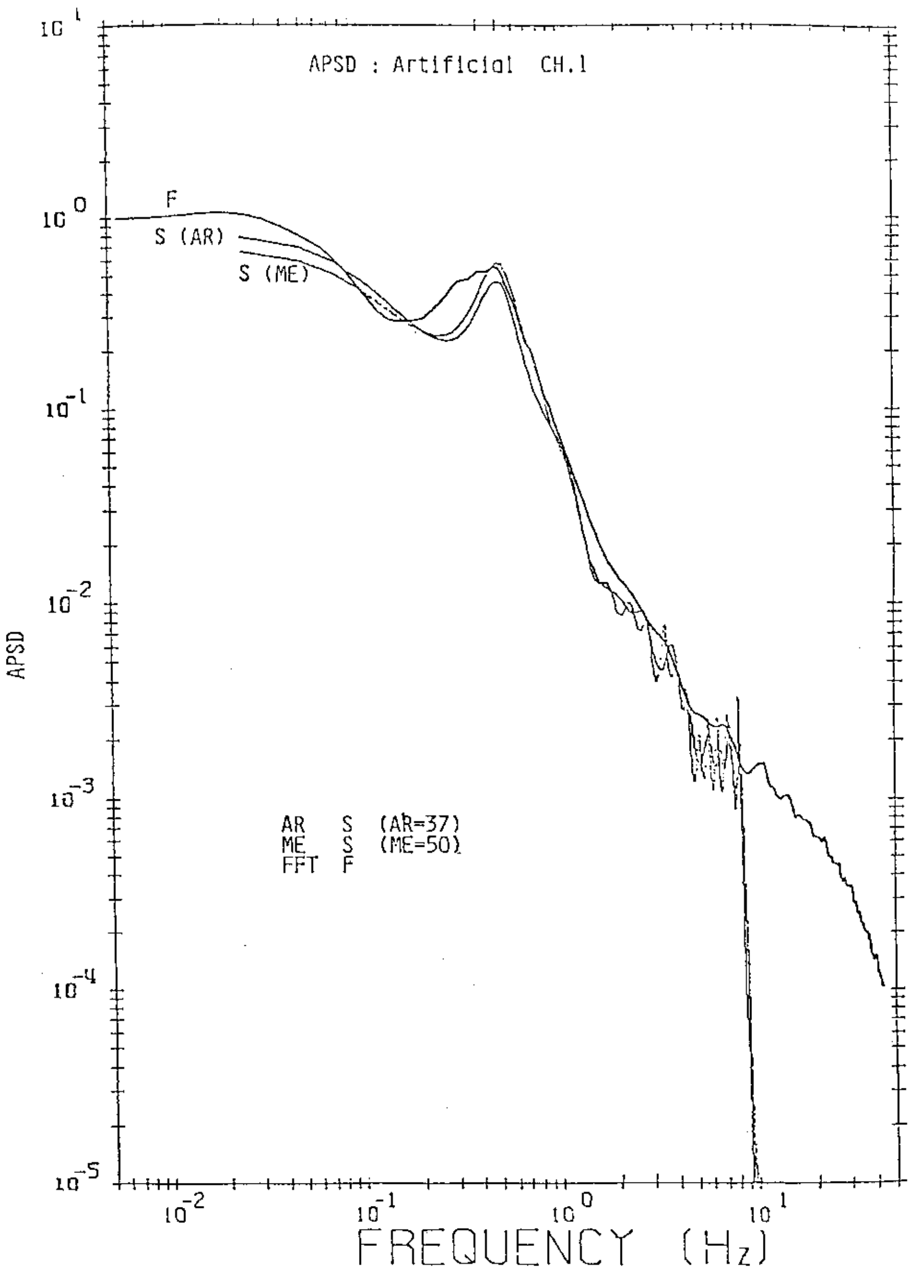

APSD : Artificial CH.1
APSD
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-2
10^-1
10^0
10^1
FREQUENCY (Hz)
F
S (AR)
S (ME)
AR S (AR=37)
ME S (ME=50)
FFT F

Fig. 2-4

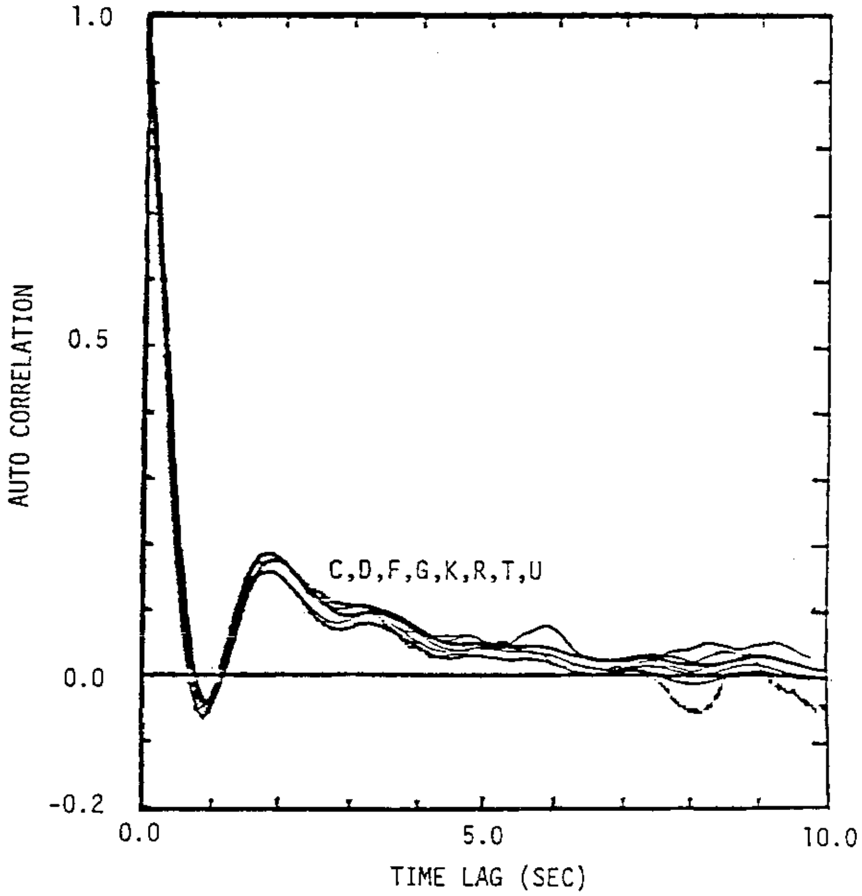


Fig. 3 Auto Correlation Function C_{11}, Artificial Noise

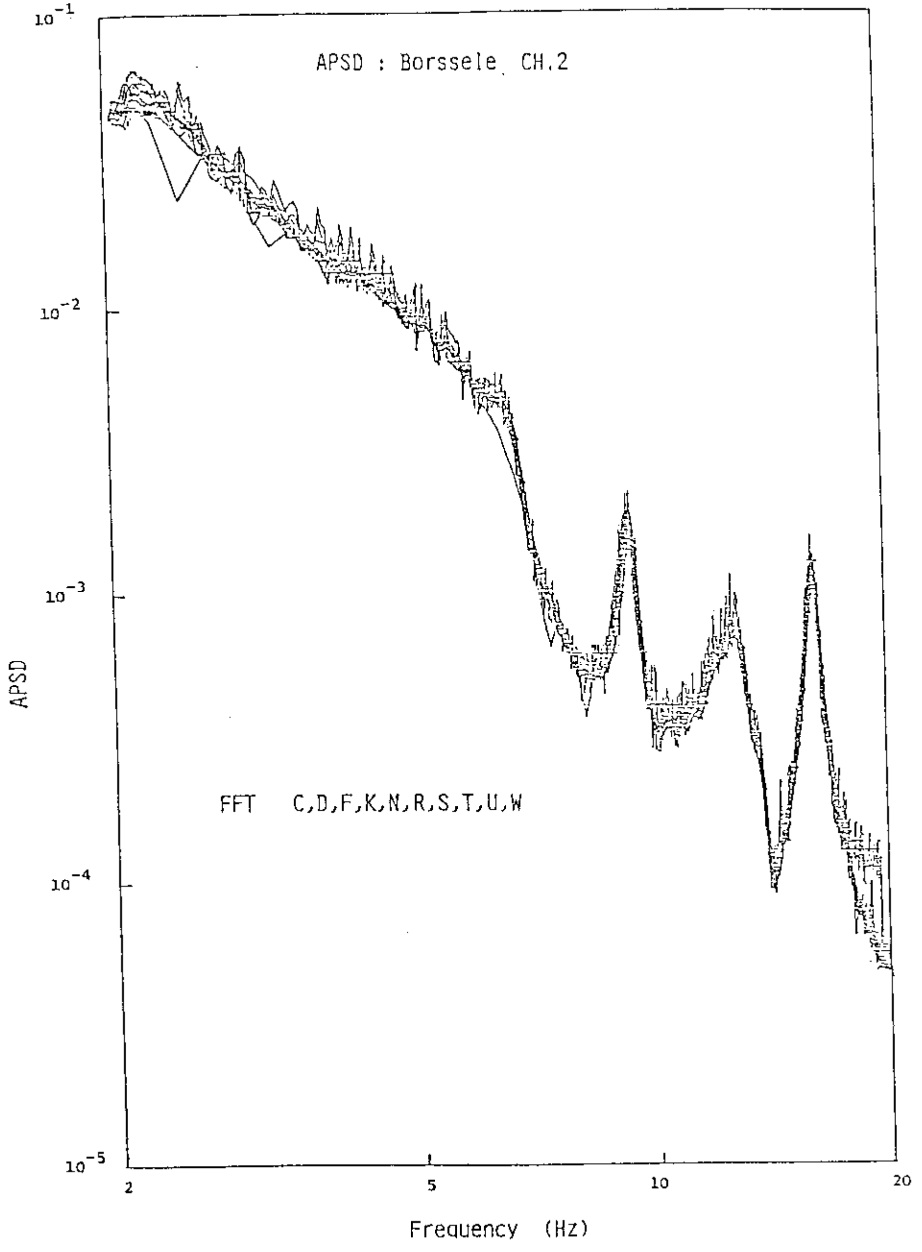

APSD : Borssele CH.2
FFT C,D,F,K,N,R,S,T,U,W
APSD
10^-1
10^-2
10^-3
10^-4
10^-5
2
5
10
20
Frequency (Hz)

FIG. 4-1

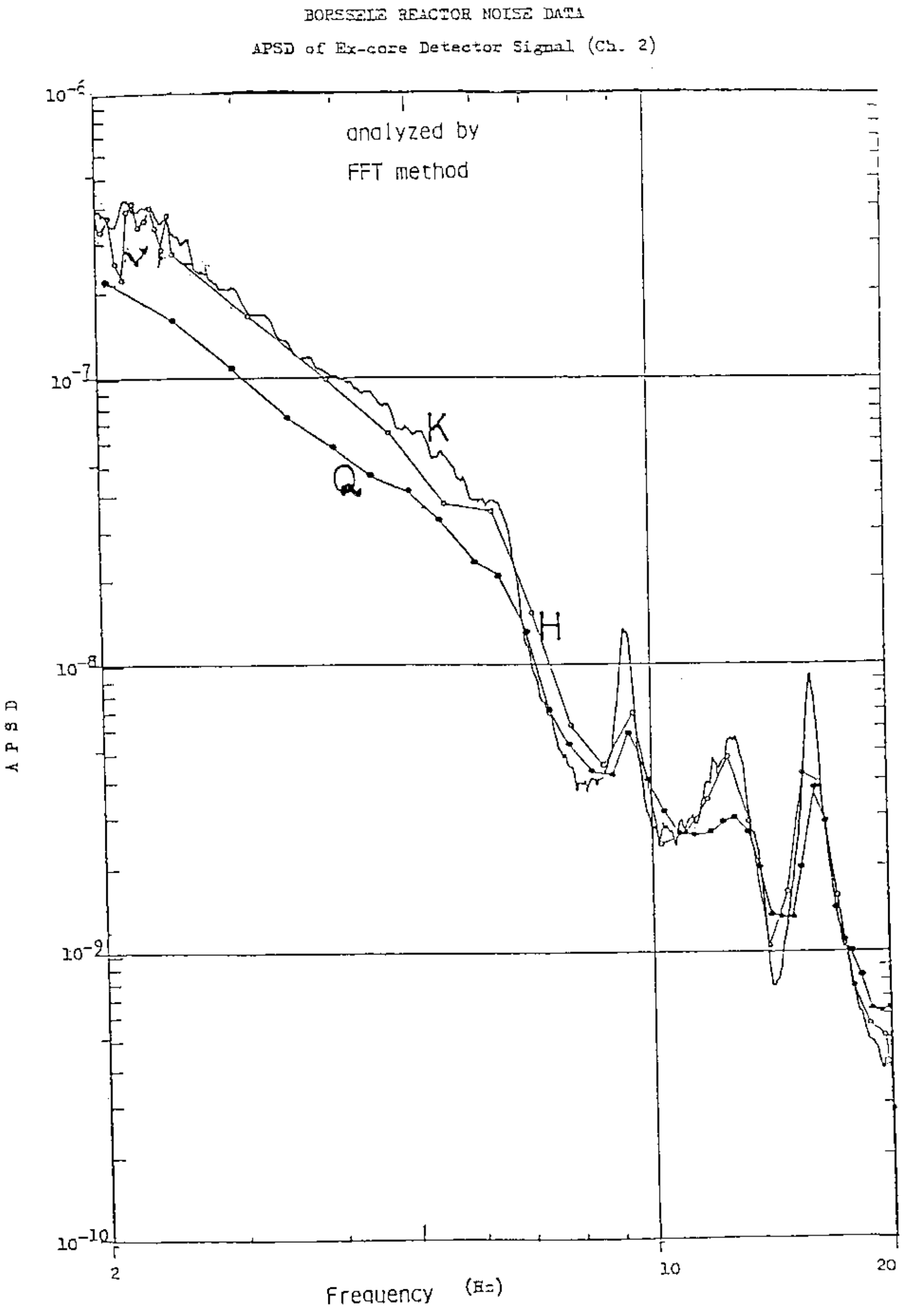

BORSSELE REACTOR NOISE DATA
APSD of Ex-core Detector Signal (Ch. 2)
analyzed by
FFT method
K
Q
H
APSD
10^-6
10^-7
10^-8
10^-9
10^-10
2
10
20
Frequency (Hz)

FIG. 4-2

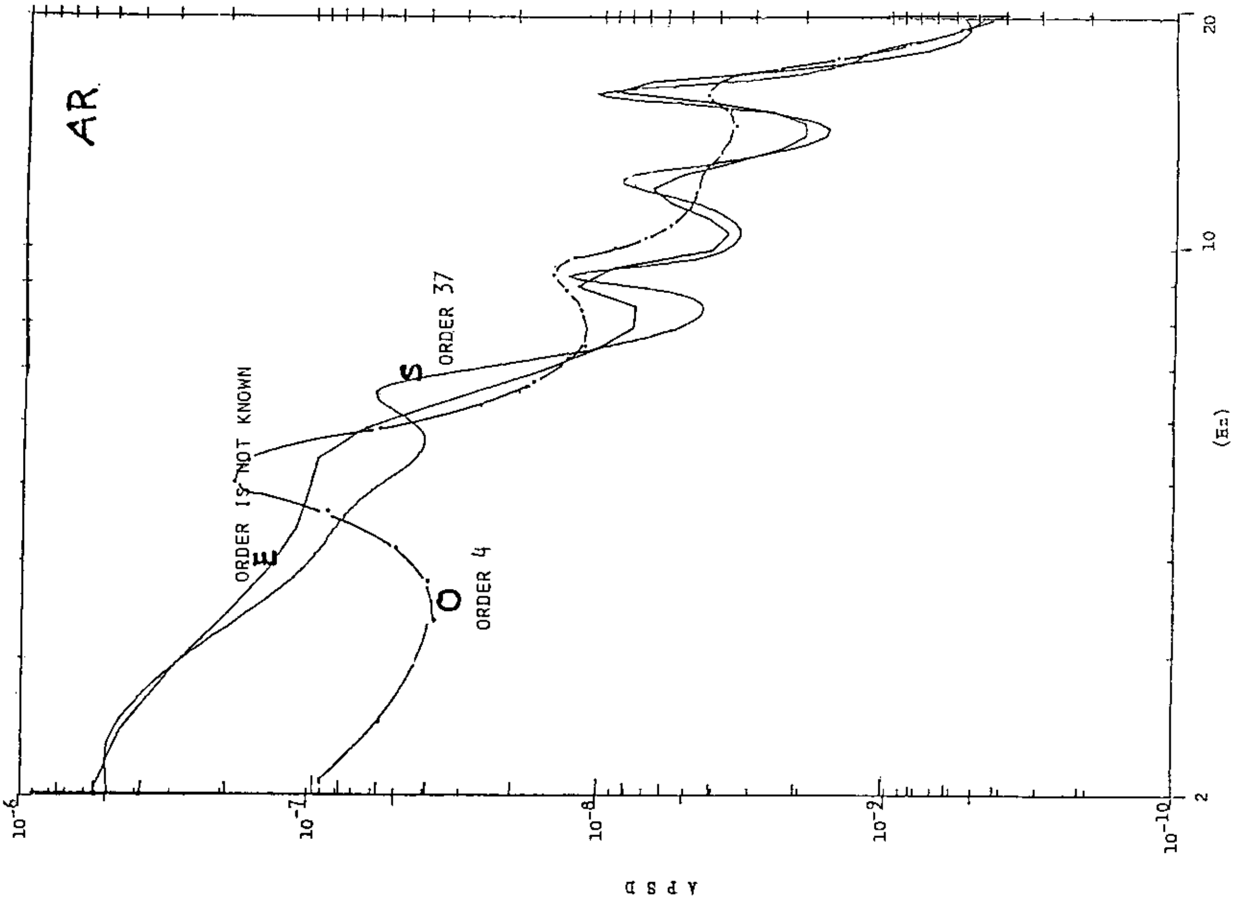

BORSSELE REACTOR NOISE DATA
APSD of Ex-core Detector Signal (Ch. 2)
AR
ORDER IS NOT KNOWN
E
O
ORDER 4
S
ORDER 37
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
APSD
2
10
20
(Hz)

FIG. 4-3

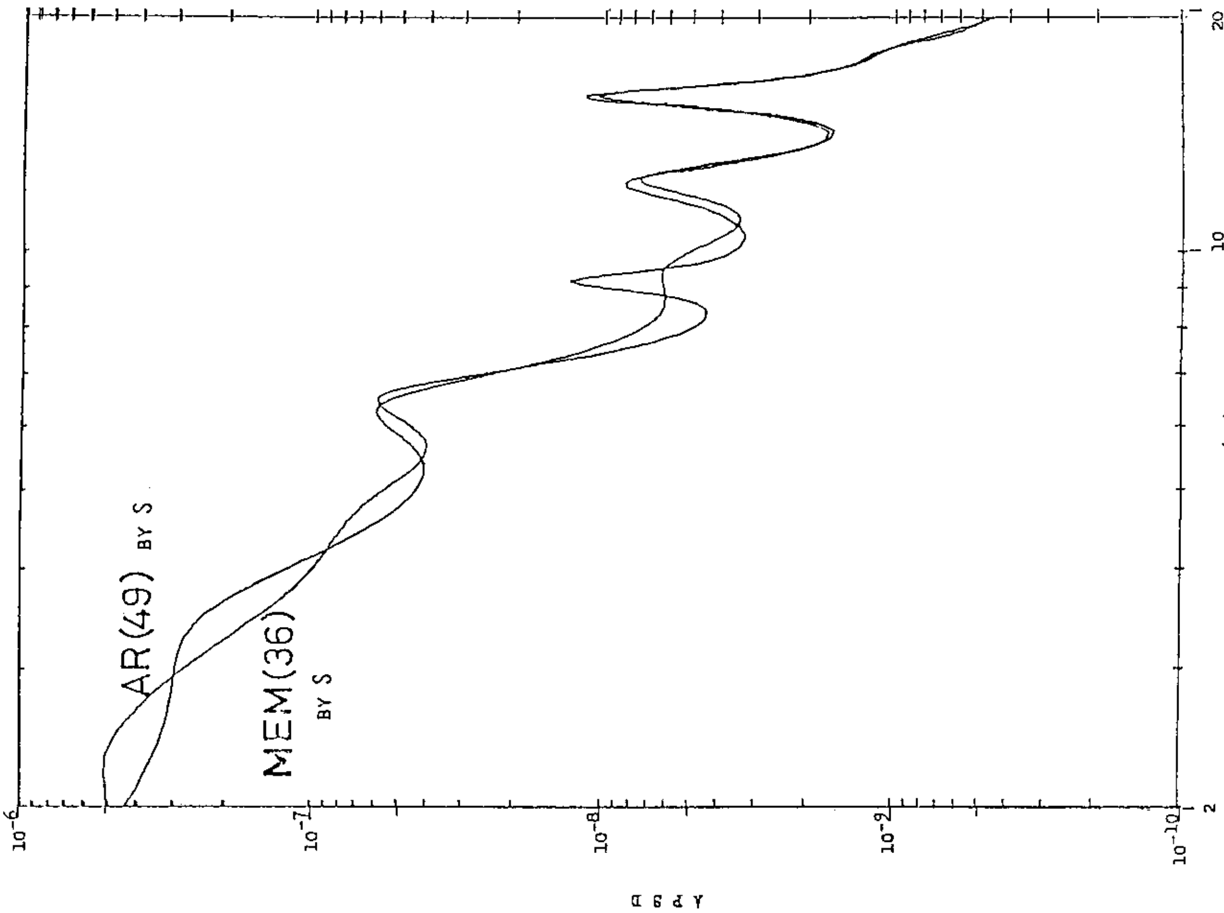

BORSSELE REACTOR NOISE DATA
APSD of Ex-core Detector Signal (Ch. 2)
AR(49) BY S
MEM(36) BY S
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
APSD
2
10
20
(Hz)

FIG. 4-4

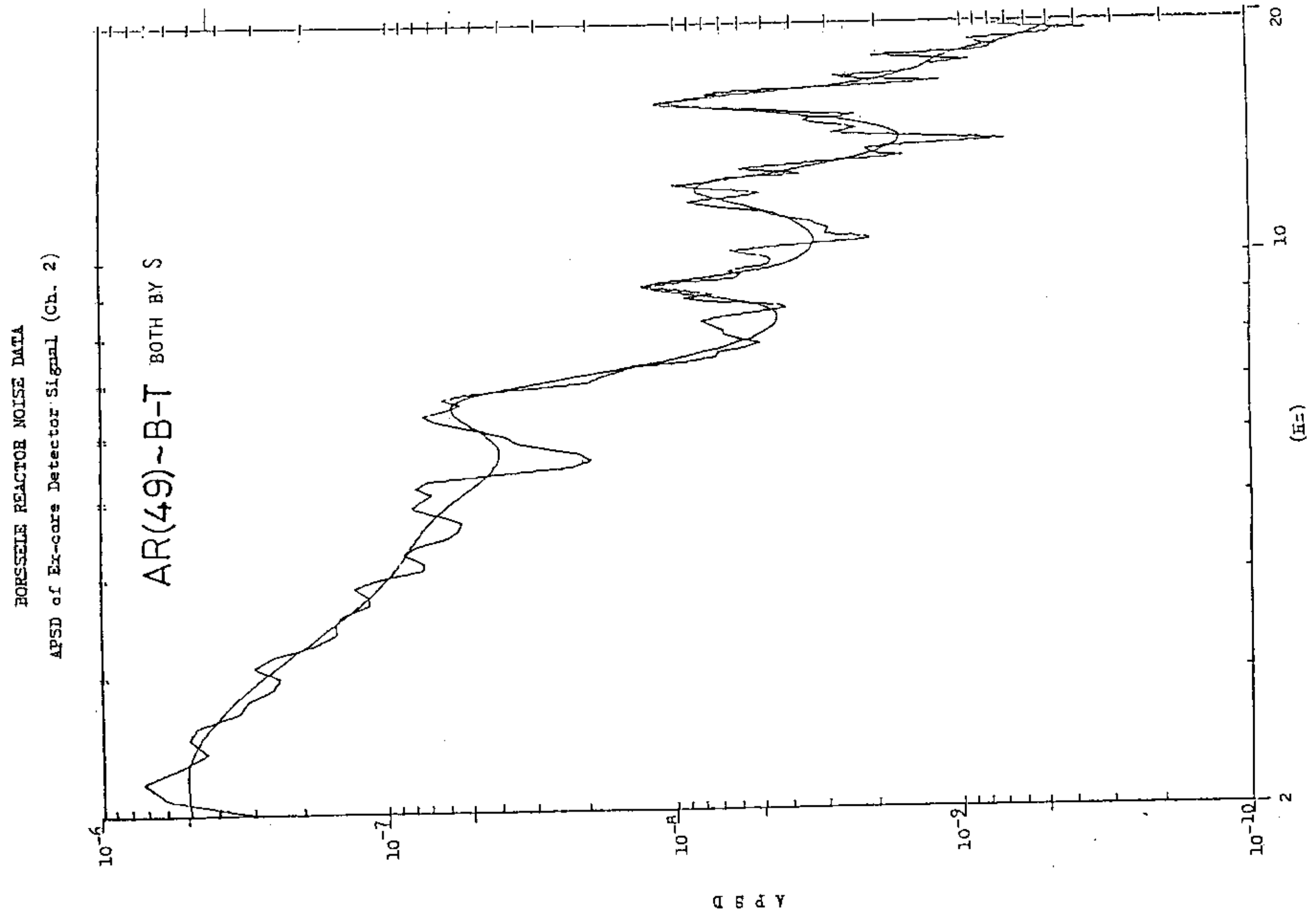

BORSSELE REACTOR NOISE DATA
APSD of Ex-core Detector Signal (Ch. 2)
AR(49)-B-T BOTH BY S
APSD
10-6
10-7
10-8
10-9
10-10
2
10
20
(Hz)

Fig. 4-5

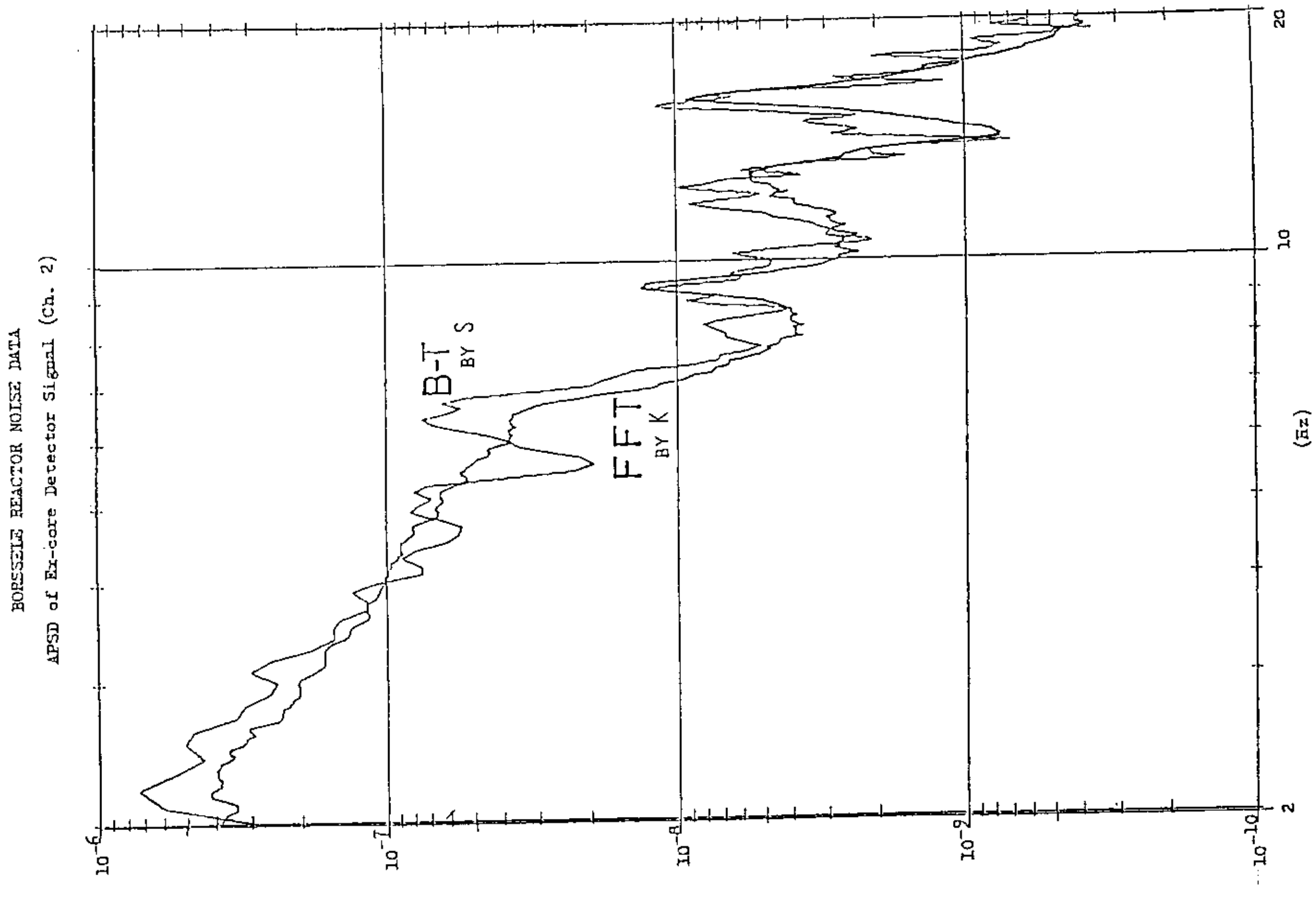

BORSSELE REACTOR NOISE DATA
APSD of Ex-core Detector Signal (Ch. 2)
B-T BY S
FFT BY K
APSD
10-6
10-7
10-8
10-9
10-10
2
10
20
(Hz)

Fig. 4-6

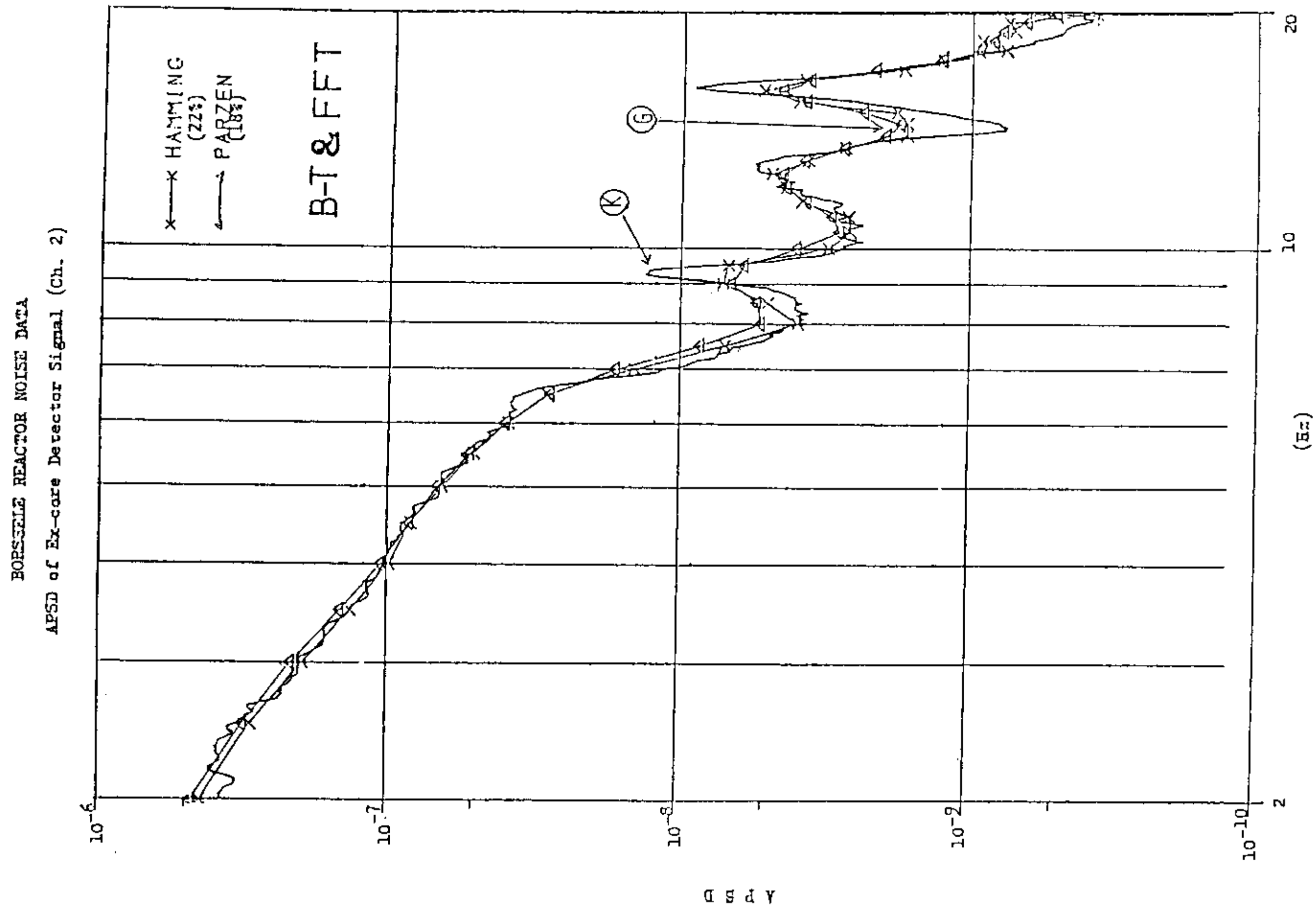

BORSSELE REACTOR NOISE DATA
APSD of Ex-core Detector Signal (Ch. 2)
HAMMING (22%)
PARZEN (18%)
B-T & FFT
K
G
APSD
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
2
10
20
(Hz)

Fig. 4-7

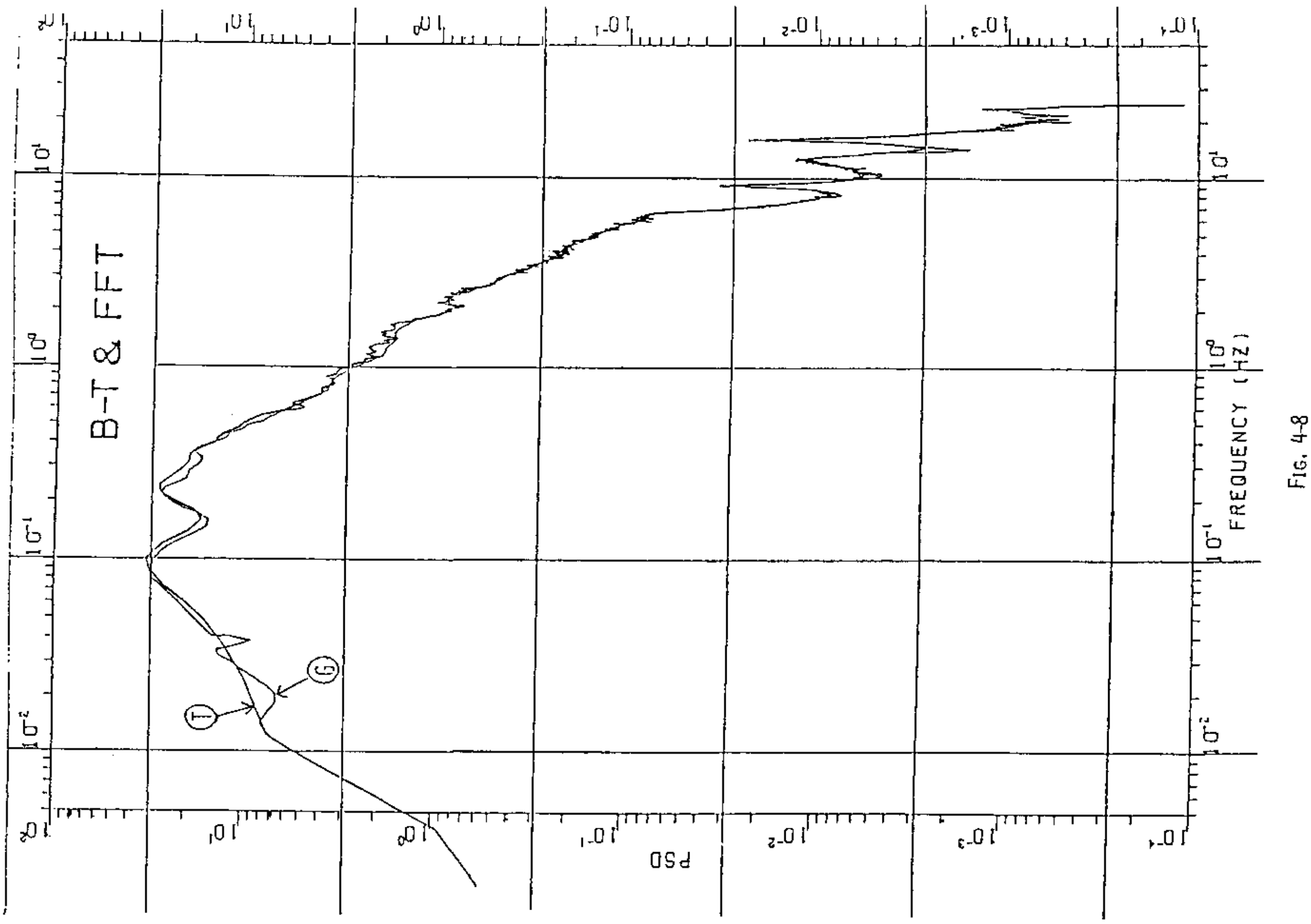

B-T & FFT
T
G
PSD
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^{0}
10^{1}
FREQUENCY (HZ)

Fig. 4-8

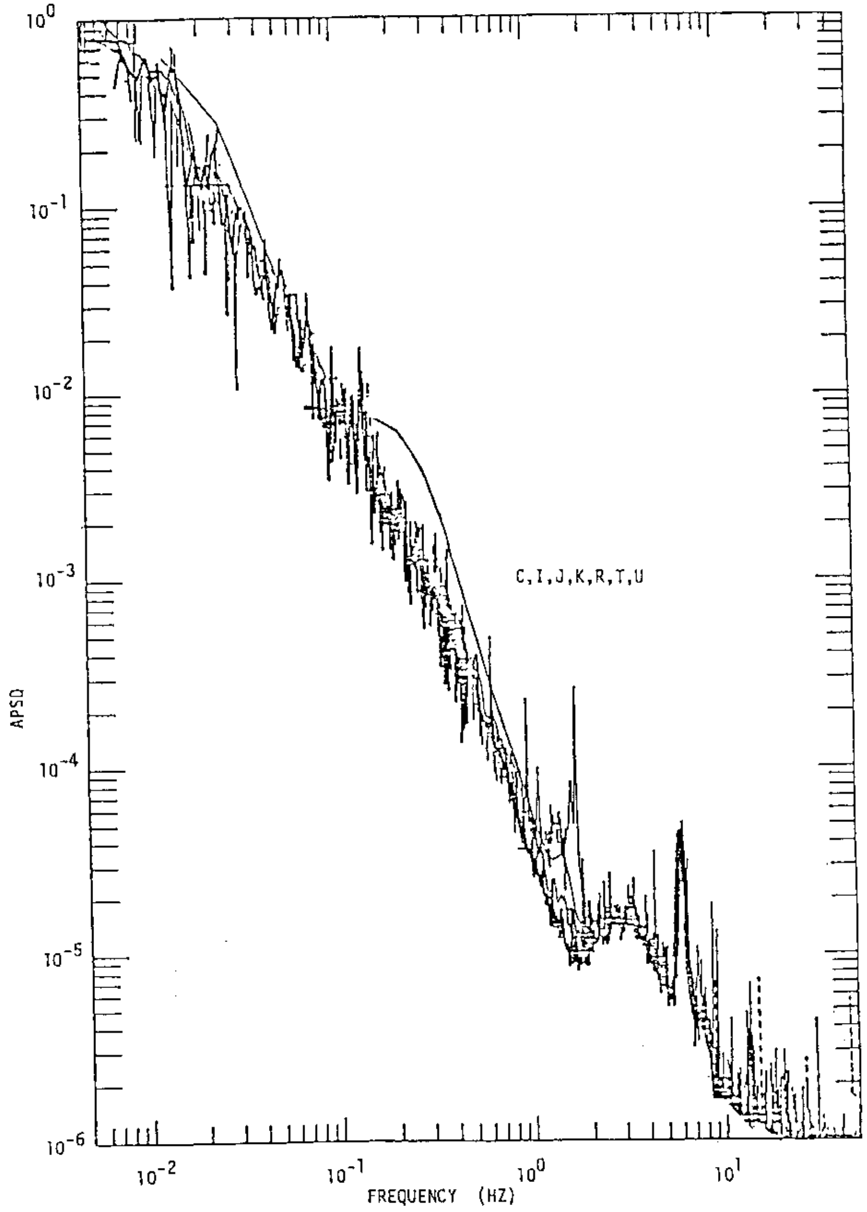


Fig. 5-1 APSD P_{11} Phenix Reactor Noise - Part 1 -

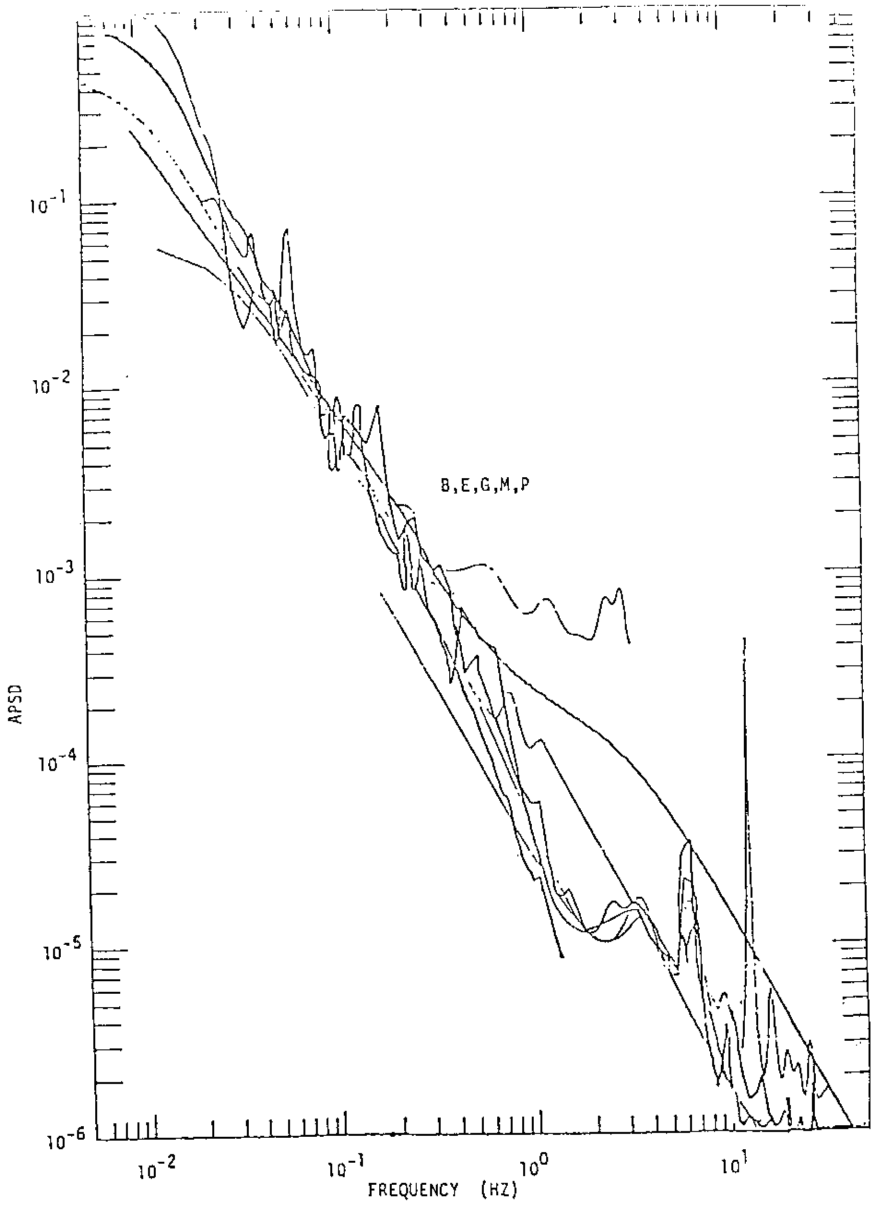
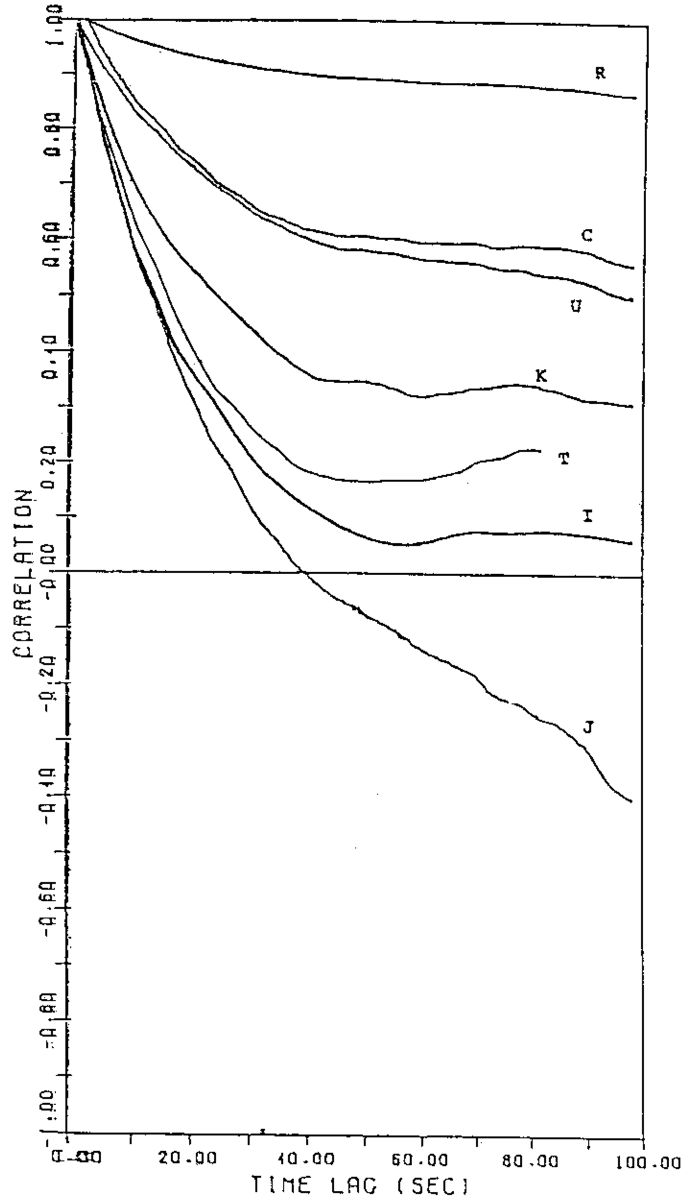
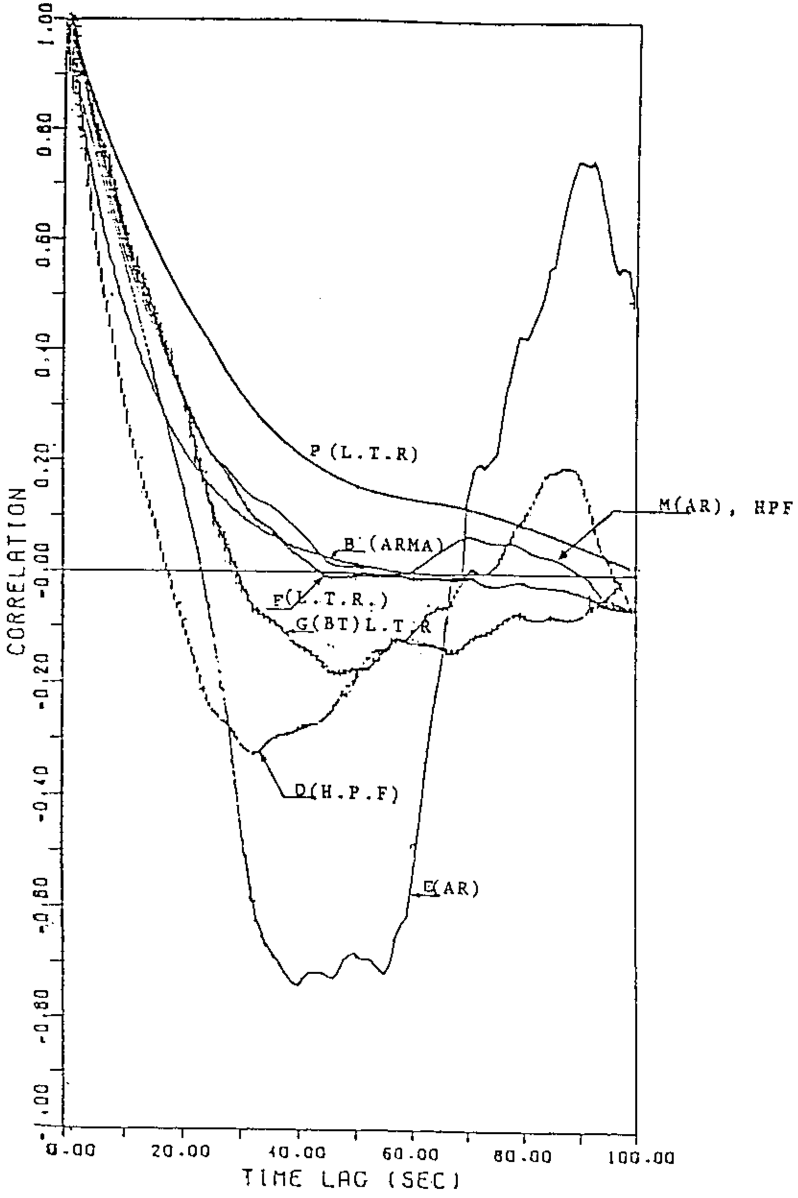


Fig. 5-2 APSD P_{11} Phenix Reactor Noise - Part 2 -



AUTO COR $C_{11}(T)$: PHENIX REACTOR NOISE - PART 1 -

FIG. 6-1



AUTO COR $C_{11}(T)$: PHENIX REACTOR NOISE - PART 2 -

FIG.6-2

APPENDIX D

Superimposed Graphs of the Computed Functions

In Table I through III are indicated the functions computed by the contributors. The names of contributors are withheld and each group of contributors are labeled with a alphabetic capital.

The graphs of computed functions submitted by different contributors are superimposed and presented in the following pages. The graphs of power spectral density functions are superimposed only from the view point of graphical pattern, not taking into account the differences in magnitude (amplitude). Therefore, the units in the ordinates for the power spectral density functions should be considered as arbitrary. There exist some errors in the size of superimposed graphs which were caused by the inaccuracy of the copying machines used. Those graphs which do not conform to the specified format are separately presented in reduced size. The comments and the graphs recently submitted by the contributor Q is also included at the end.

The notations used in this Appendix are as follows.

C_{ii} : Normalized auto-correlation function for the signals recorded on the i-th track of the data tape.

C_{ij} : Normalized cross-correlation function for the signals recorded on the i-th and j-th tracks.

P_{ii} : Auto-power spectral density function for the signal recorded on the i-the track.

P_{ij} : Amplitude of cross-power spectral density function for the signals recorded on the i-th and j-th tracks.

Coh : Coherence function for the signals recorded on the i-th and j-th tracks.

Ph : Phase of the corss-power spectral density function.

Table I. Functions Computed for Artificial Noise

Label of Contributor	Functions													
	0-10sec			0-100sec			0.005-50Hz			0.2-2.0Hz			0.005-50Hz	
	C_{11}	C_{22}	C_{12}	C_{11}	C_{22}	C_{12}	P_{11}	P_{22}	P_{12}	P_{11}	P_{22}	P_{12}	Coh	Ph
A	#	#	#				*	*	#	*	*	#	#	#
B	*	*	*		*		*	*	*	*	*	*	*	*
C	*	*	*	*	*	*	*	*	*	*	*	*	*	*
D	*	*	*		*	*	*	*	*	*	*	*	*	*
E	*	*	*		*		*	*	*	*	*	*	*	*
F	*	*	*	*	*	*	*	*	*	*	*	*	*	*
G	*	*	*		*		*	*	*	*	*		*	*
H	*	*	*				*	*	*	*	*	*	*	*
I														
J	*	*	*	*	*	*	*	*	*	*	*	*	*	*
K	*	*	*				*	*	*	*	*	*	*	*
L	*	*	*				*	*	*	#	#	#	*	*
M				*	*	*	*	*	*				*	*
N	#	#	#				*	*	*	*	*	*	*	*
O							*	*		*	*			
P	*	*	*	*	*	*	*	*	*				*	*
Q							*	*	*	*	*	*	*	*
R	*	#	*				*	*	*	*	*	*	*	*
S	*	*	*				*	*	*	*	*		*	*
T	*	*	*		*	*	*	*	*	*	*	*	*	*
U	*		*	*	*	*	*	*	*	*	*	*	*	*
W	*	*	#				*	*	#	*	*	*	*	#
X	#	#	#	#	#	#	#	#	#	#	#	#	#	#

Symbols: * - Graphs conforming to the specified format
- Graphs not conforming to the specified format

Table II. Functions Computed for Borssele Reactor Noise

Label of Contributor	Functions										
	0-10sec			0.005-50Hz			2.0-20Hz			0.005-50Hz	
	C_{11}	C_{22}	C_{12}	P_{11}	P_{22}	P_{12}	P_{11}	P_{22}	P_{12}	Coh	Ph
A	#	#	#	*	*	#	*	#	#	#	#
B	*	*	*	*	*	*	*	*	*	*	*
C	*	*	*	*	*	*	*	*	*	*	*
D	*	*	*	*	*	*	*	*	*	*	*
E	*	*	*	*	*	*	*	*	*	*	*
F	*	*	*	*	*	*	*	*	*	*	*
G	*	*	*	*	*	*	*	*		*	*
H	*	*	*	*	*	*	*	*	*	*	*
I	#	#	#	*	*	*				*	*
J	*	*	*	*	*	*	*	*	*	*	*
K	*	*	*	*	*	*	*	*	*	*	*
L	*	*	*	*	*	*	#	#	#	*	*
M	*	*	*	*	*	*				*	*
N	#	#	#	*	*	*	*	*	*	*	*
O				*	*		*	*			
P	*	*	*	*	*	*				*	*
Q				*	*	*	*	*	*	*	*
R	*	*	*	*	*	*	*	*	*	*	*
S	*	*	*	*	*	*	*	*		*	*
T	*	*	*	*	*	*	*	*	*	*	*
U	*	*	*	*	*	*	*	*	*	*	*
W	*	*	#	*	*	#	*	*	*	#	#
X	#	#	#	#	#	#	#	#	#	#	#

Symbols: * - Graphs conforming to the specified format

- Graphs not conforming to the specified format

Table III. Functions Computed for Phenix Reactor Noise

Label of contributor	Functions													
	0-10sec			0-100sec			0.005-50Hz			0.1-1.0Hz			0.005-50Hz	
	C_{11}	C_{55}	C_{15}	C_{11}	C_{55}	C_{15}	P_{11}	P_{55}	P_{15}	P_{11}	P_{55}	P_{15}	Coh	Ph
A	#	#	#	#	#	#	*	*	#	*	*	#	#	#
B	*	*	*	*	*	*	*	*	*	*	*	*	*	*
C	*	*	*	*	*	*	*	*	*	*	*	*	*	*
D	*	*	*	*	*	*	*	*	*	*	*	*	*	*
E	*	*	*	*			*	*	*	*	*	*	*	*
F	*	*	*	*	*	*	*	*	*	*	*	*	*	*
G				*	*	*	*	*	*	*	*		*	*
H	*	*	*				*	*	*	*	*	*	*	*
I				*	*	*	*	*	*				*	*
J	*	*	*	*	*	*	*	*	*	*	*	*	*	*
K	*	*	*	*	*	*	*	*	*	*	*	*	*	*
L														
M				*	*	*	*	*	*				*	*
N	#	#	#	#	#	#	*	*	*	*	*	*	*	*
O							*	*		*	*			
P	*			*			*							
Q							*	*	*	*	*	*	*	*
R		*	*	*			*	*	*	*	*	*	*	*
S	*	*	*				*	*	*	*	*		*	*
T	*	*	*	*	*	*	*	*	*	*	*	*	*	*
U				*	*	*	*	*	*	*	*	*	*	*
W	*	*	#							*	*	*	#	#
X	#	#	#	#	#	#	#	#	#	#	#	#	#	#

Symbols: * - Graphs conforming to the specified format

- Graphs not conforming to the specified format

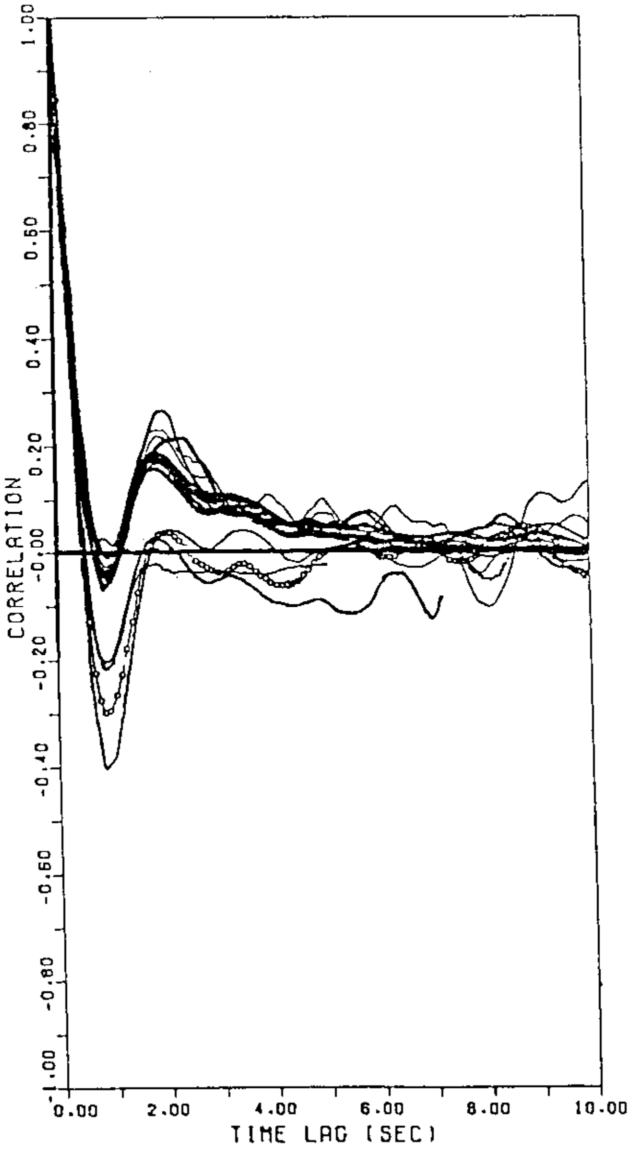


Fig. 1 C_{11} for Artificial noise data computed by B,C,D,E,F,G,H,J,K,L,P,R,S,T,U,W

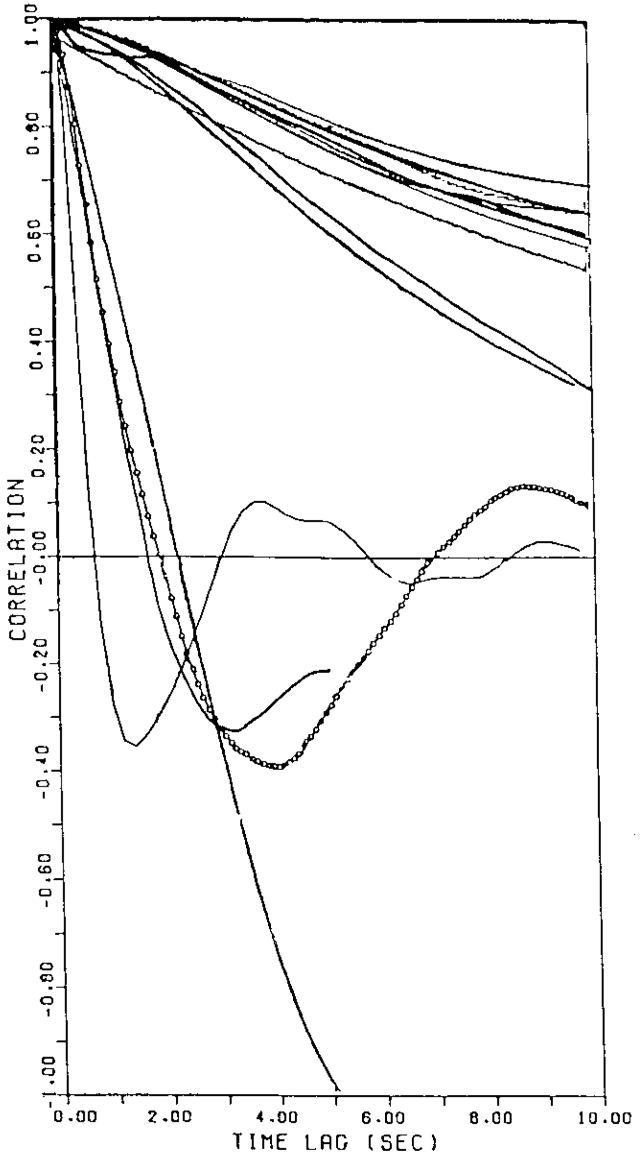


Fig. 2 C_{22} for Artificial noise data computed by B,C,D,E,F,G,H,J,K,L,P,S,T,W

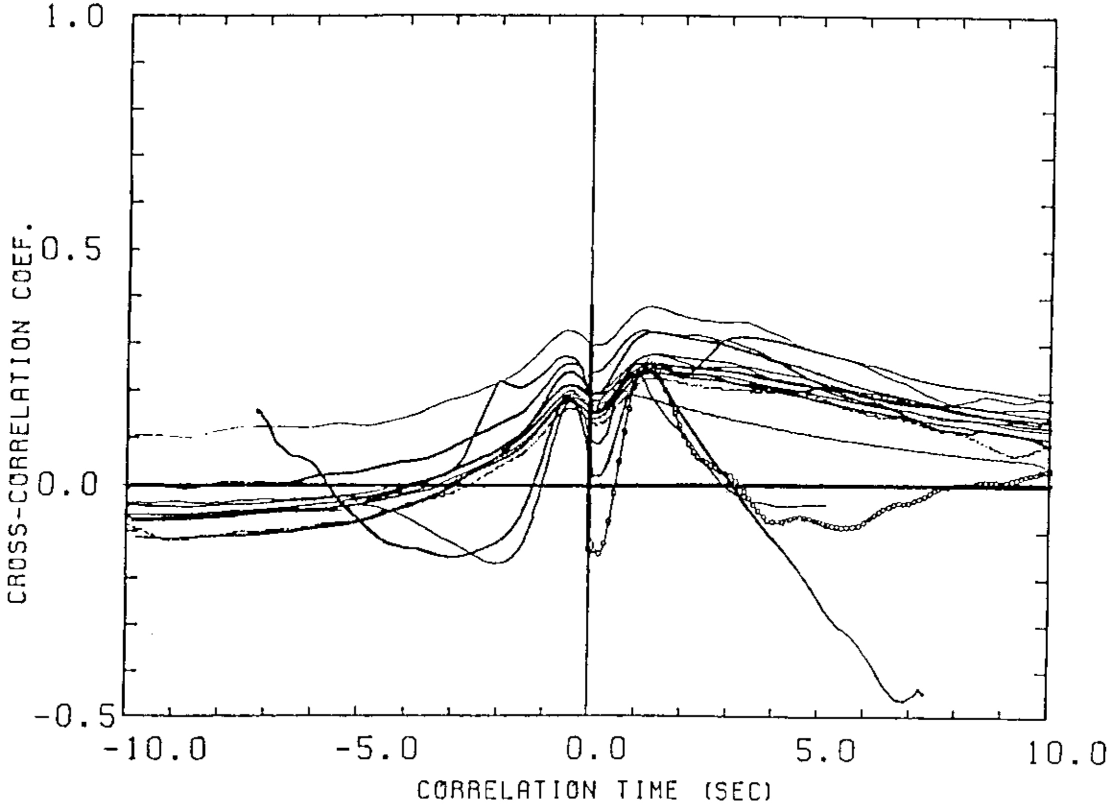


Fig. 3 C_{12} for Artificial noise data computed by B,C,D,E,F,G,H,J,K,L,P,R,S,T,U

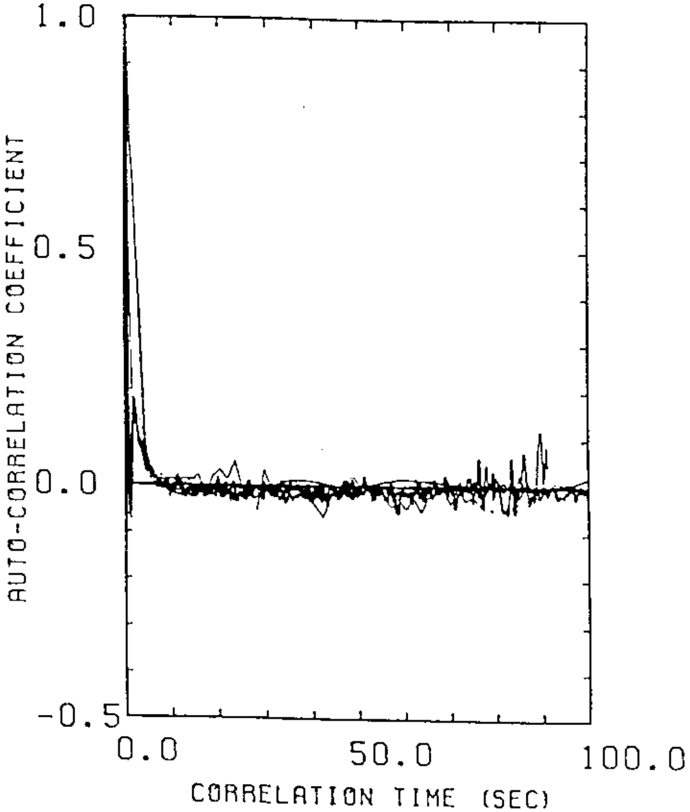


Fig. 4 C_{11} for Artificial noise data computed by C,F,J,M,P,U

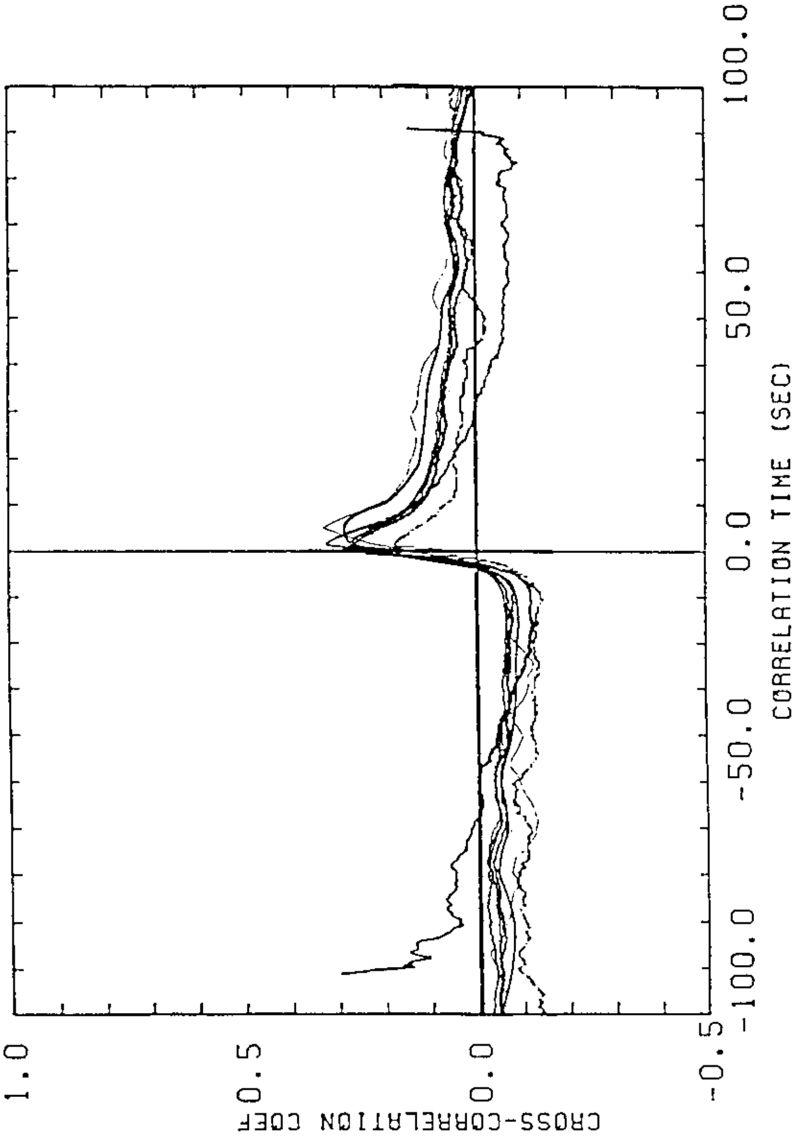


Fig. 6 C_{12} for Artificial noise data computed by C,D,F,J,M,P,T,J

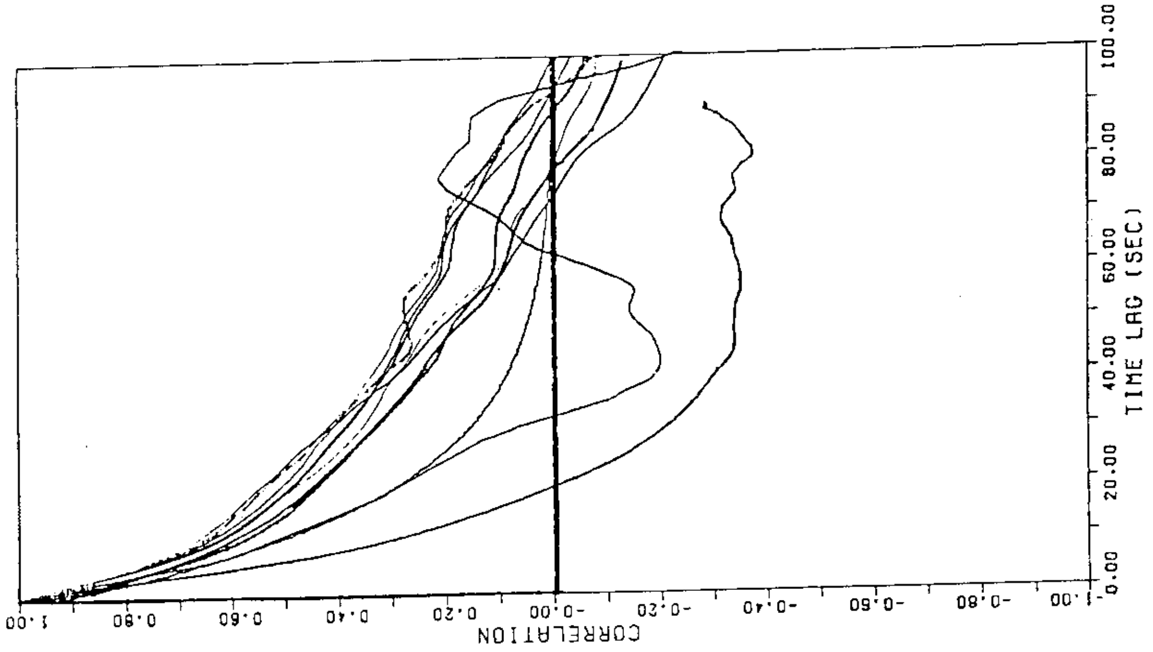


Fig. 5 C_{22} for Artificial noise data computed by B,C,D,E,F,G,J,M,P,T,U

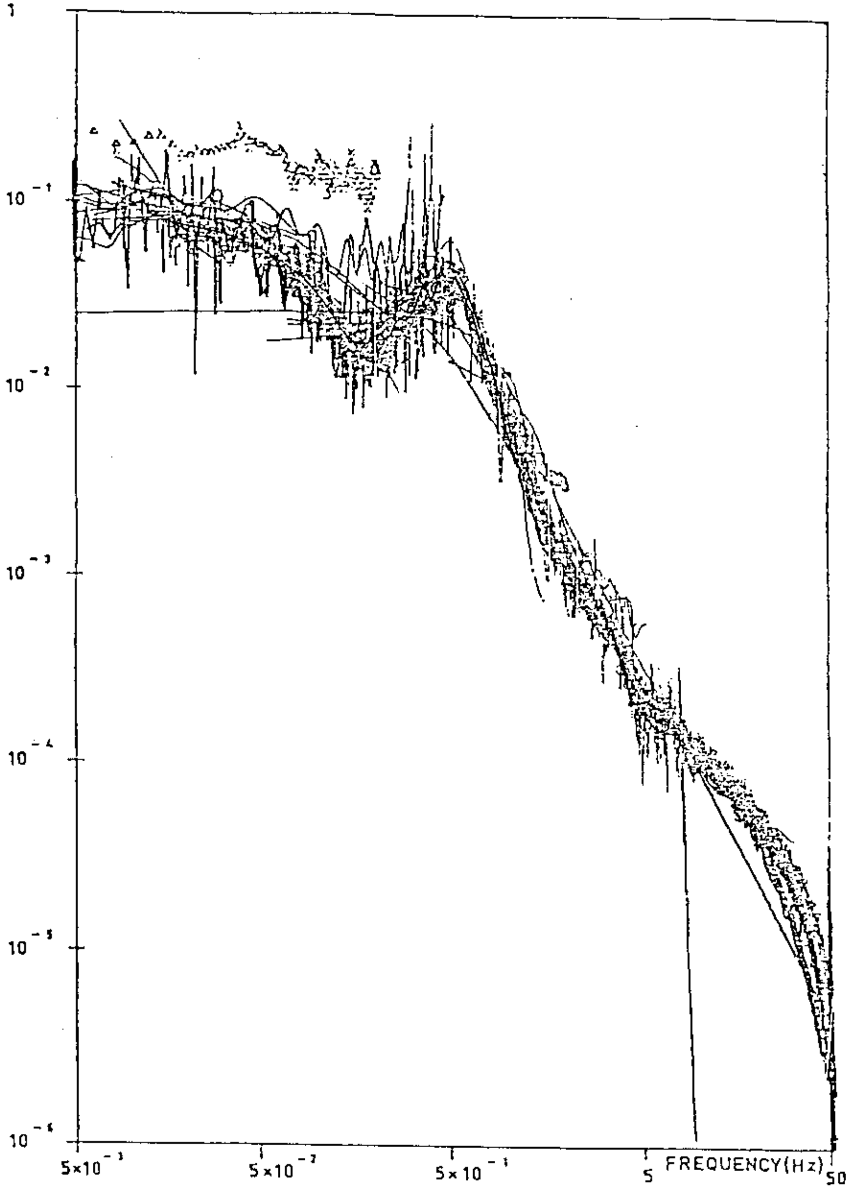


Fig. 7 P_{11} for Artificial noise data computed by A,B,C,D,E,F,G,H,J,K,L,M,N, O,P,Q,R,S,T,U,W

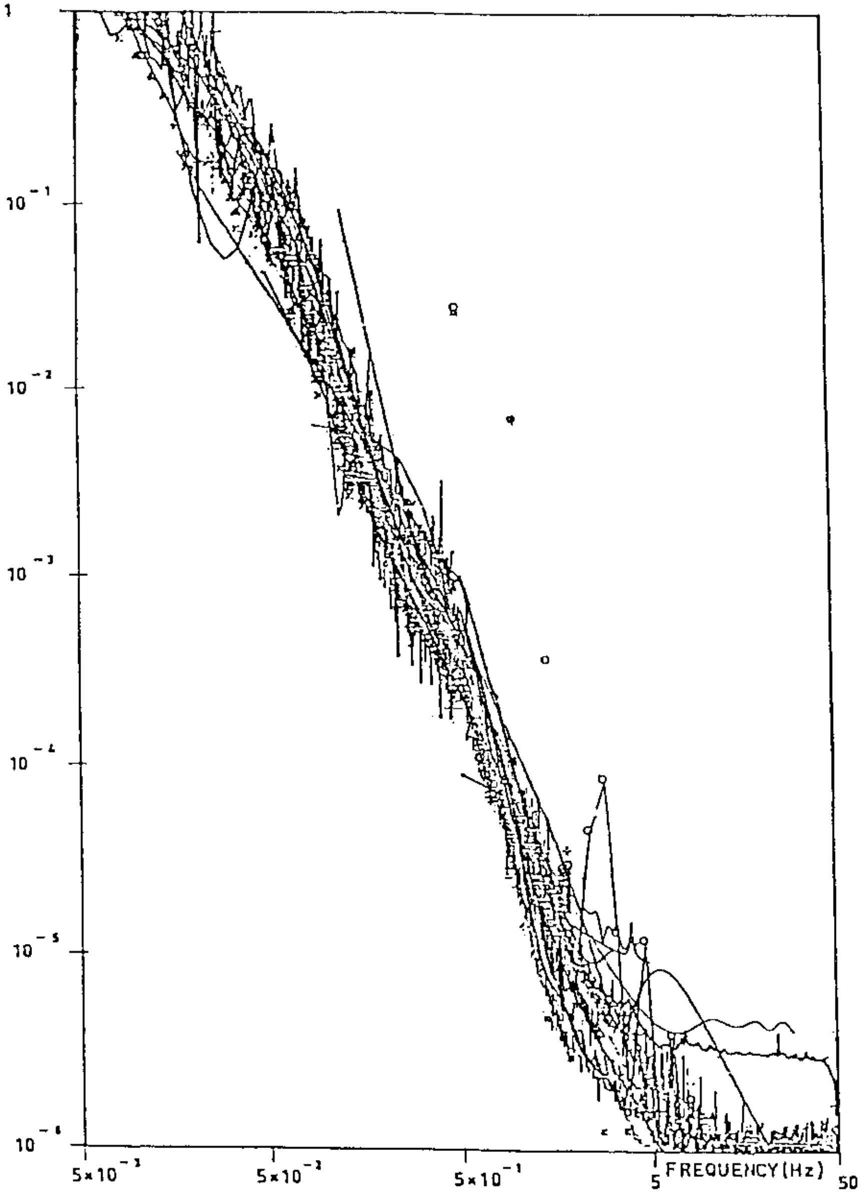


Fig. 8 P_{22} for Artificial noise data computed by A,B,C,D,E,F,G,H,J,K,L,M,N, O,P,Q,R,S,T,U,W

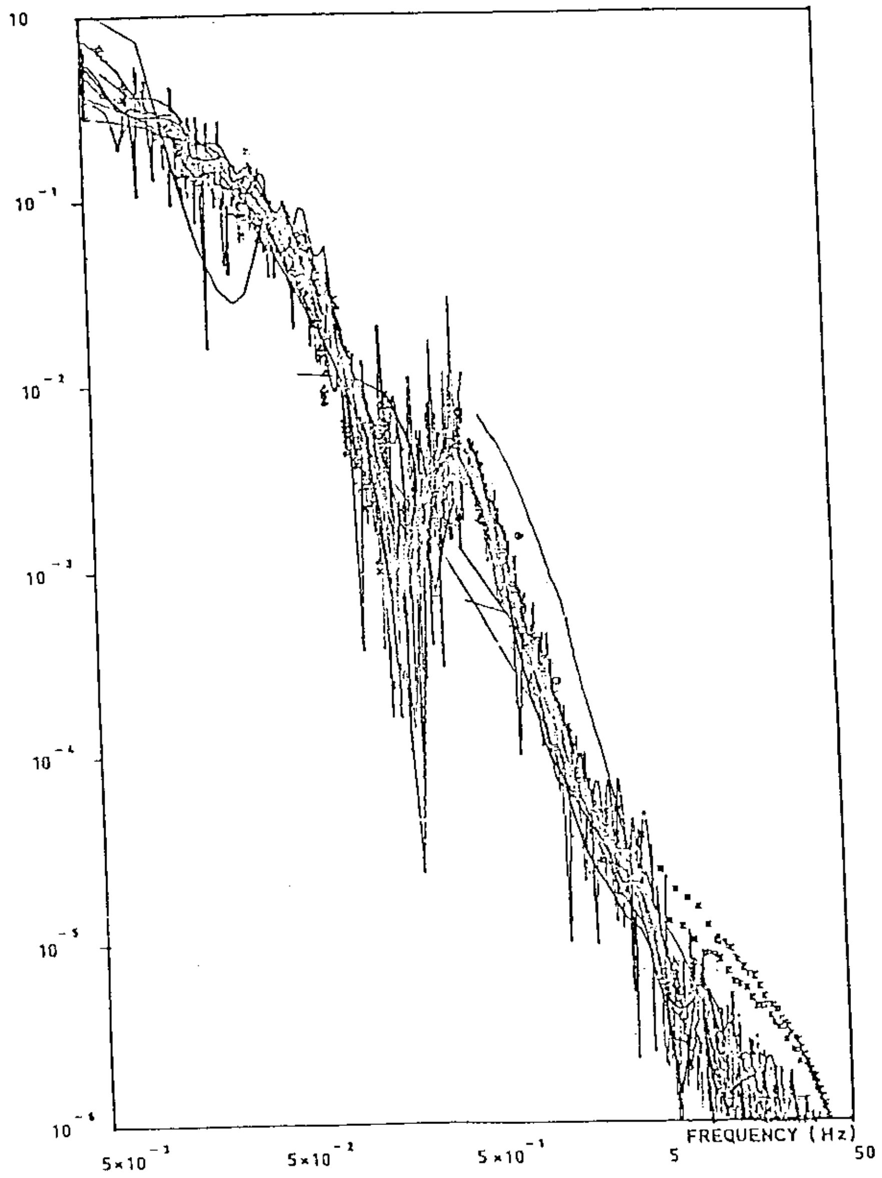


Fig. 9 P_{12} for Artificial noise data computed by B,C,D,E,F,G,H,J,K,L,M,N, P,Q,R,S,T,U

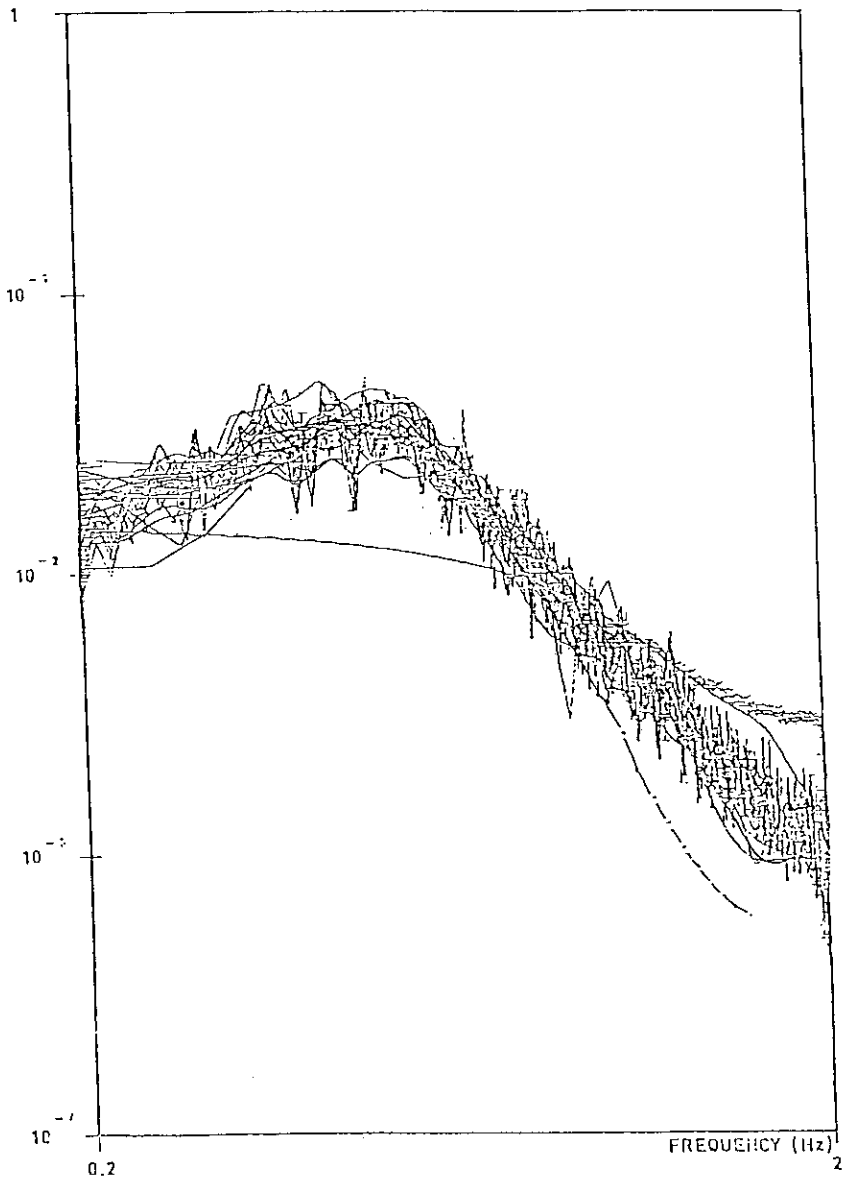


Fig. 10 P_{11} for Artificial noise data computed by A,B,C,D,E,F,G,H,J,K,N,O, Q,R,S,T,U,W

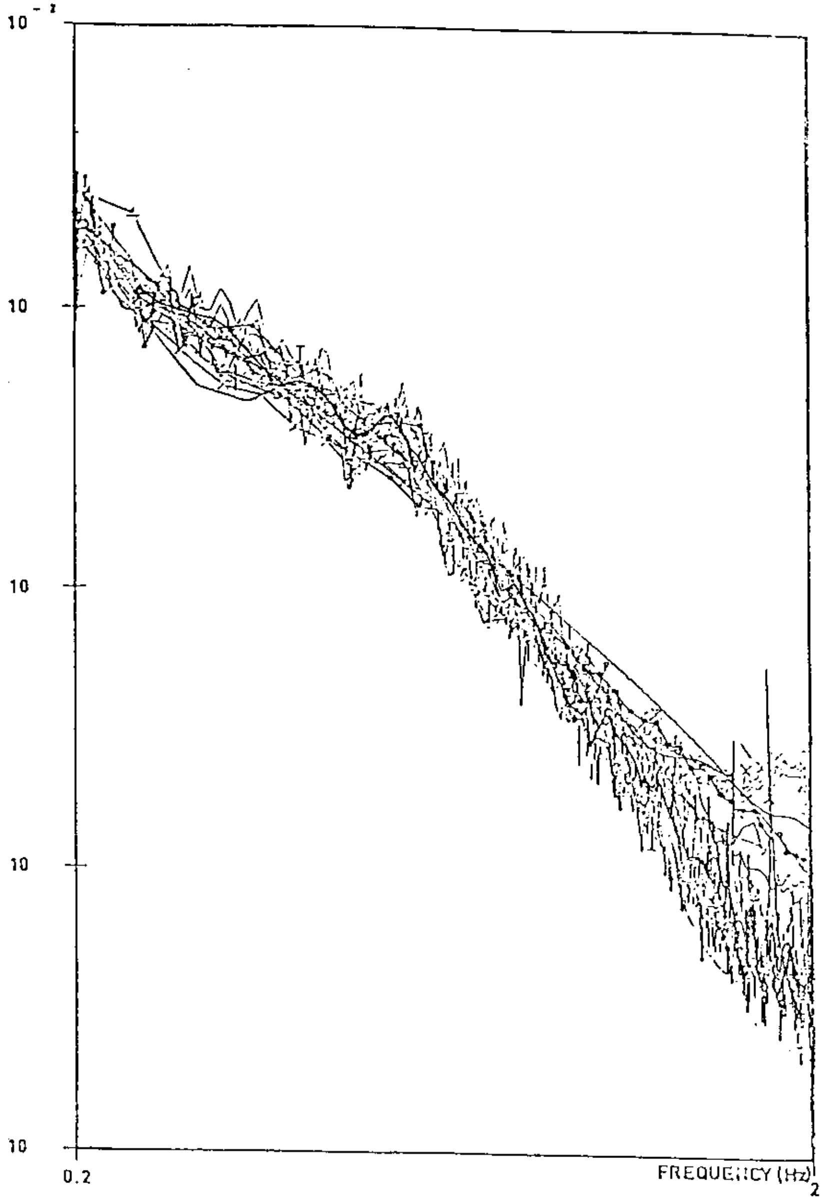


Fig. 11 P_{22} for Artificial noise data computed by A,B,C,D,E,F,G,H,J,K,N,O, Q,R,S,T,U,W

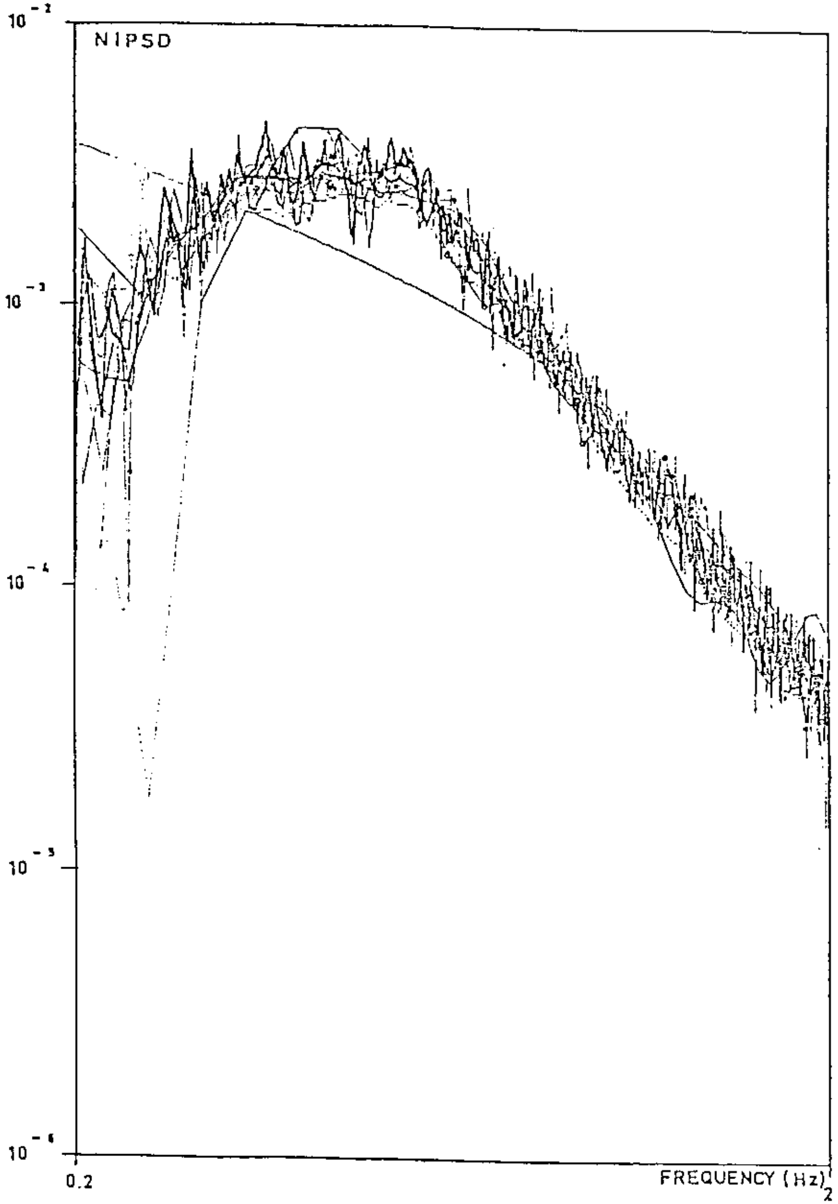


Fig. 12 P_{12} for Artificial noise data computed by B,C,D,E,F,H,J,K,N,Q,R,T,U,W

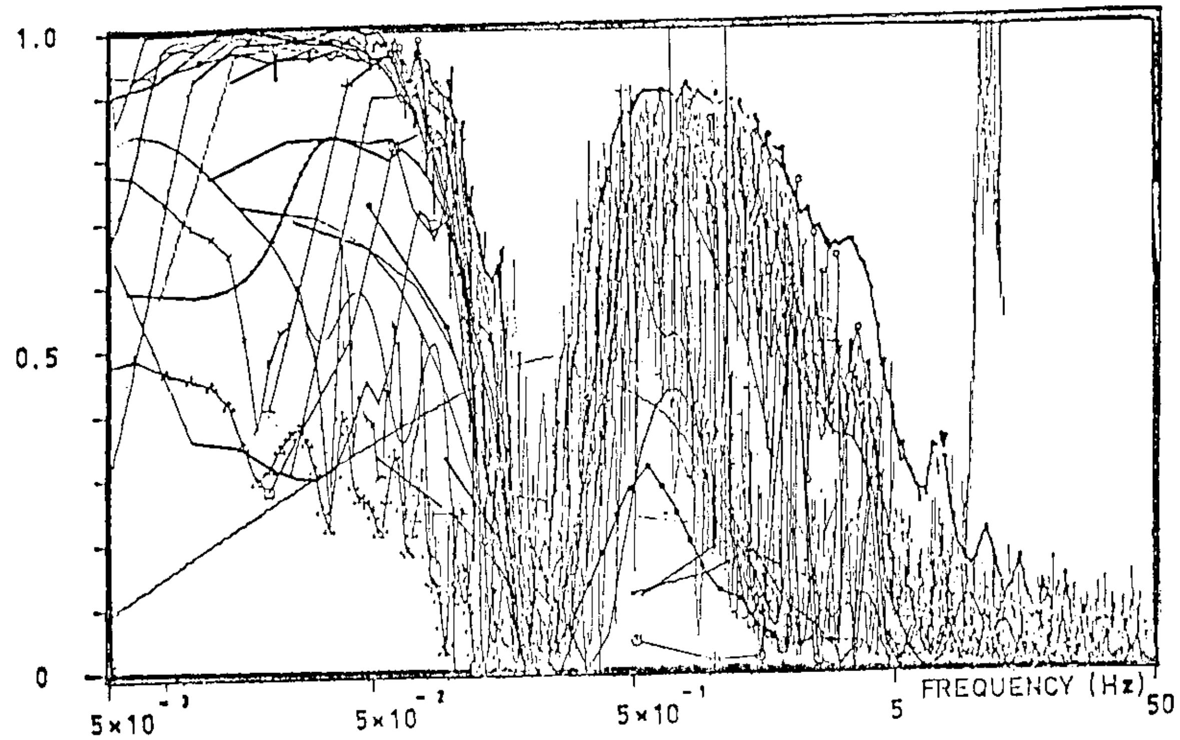


Fig.13 Coh for Artificial noise data
computed by B,C,D,E,F,G,H,J,K,L,M,N,P,Q,R,S,T,U,W

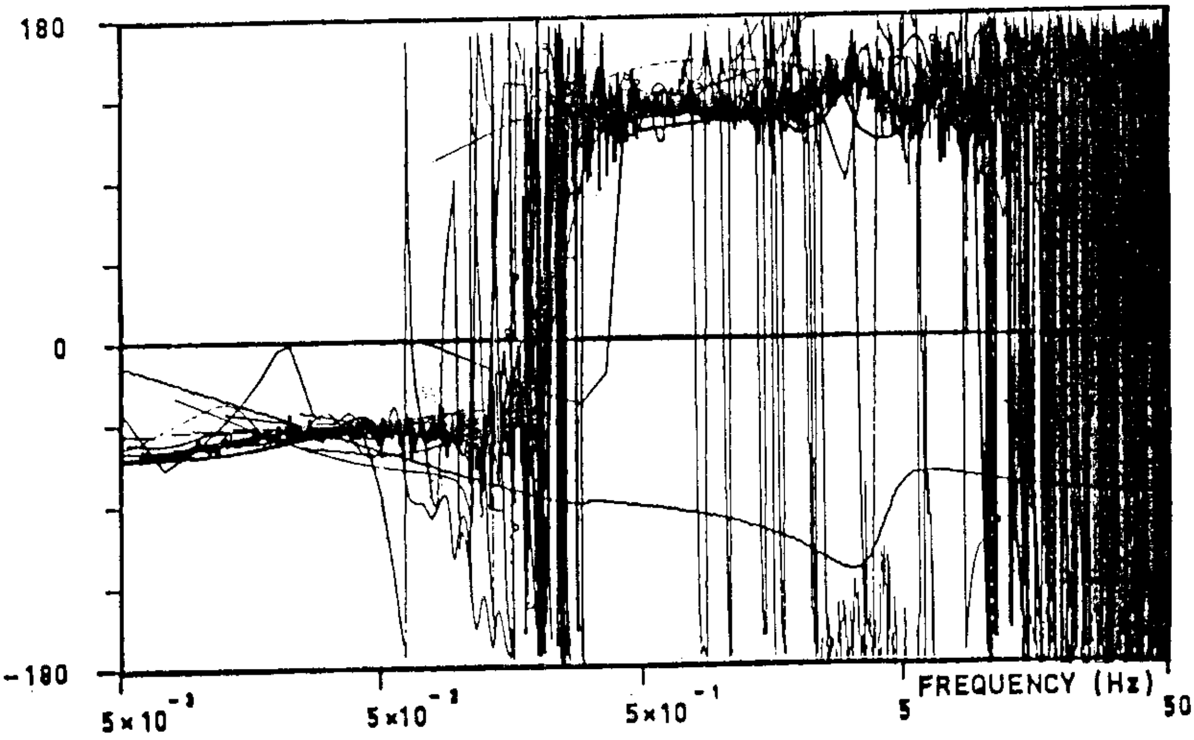


Fig.14 Ph for Artificial noise data
computed by B,C,D,E,F,G,H,J,K,L,M,N,P,Q,R,S,T,U

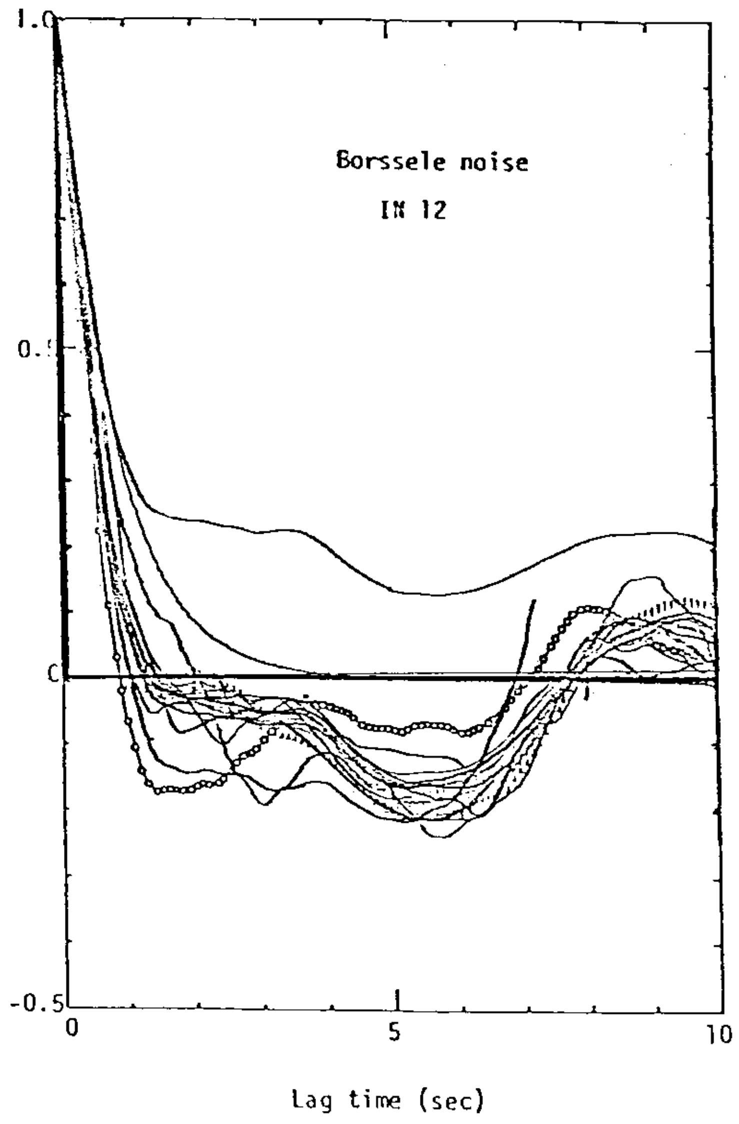


Fig.15 C_{11} for Borssele noise data computed by B,C,D,E,F,G,H,J,K,L,M,P,R,S,T,U,W

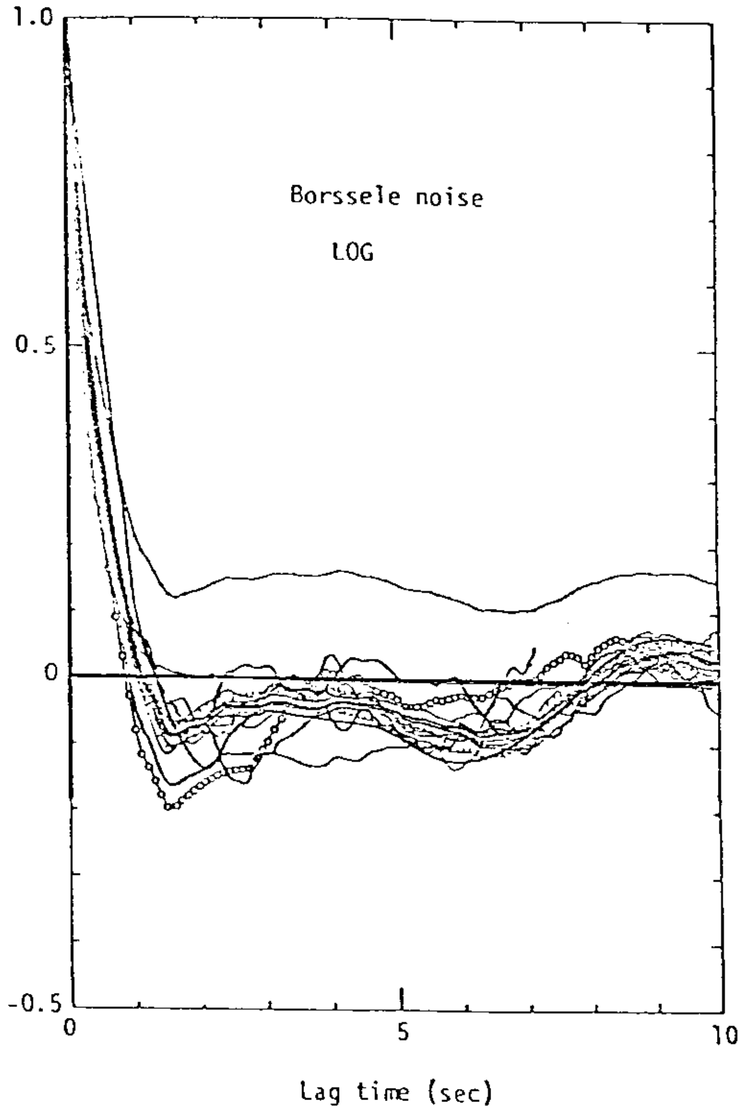


Fig.16 C_{22} for Borssele noise data computed by B,C,D,E,F,G,H,J,K,L,M,P,R,S,T,U,W

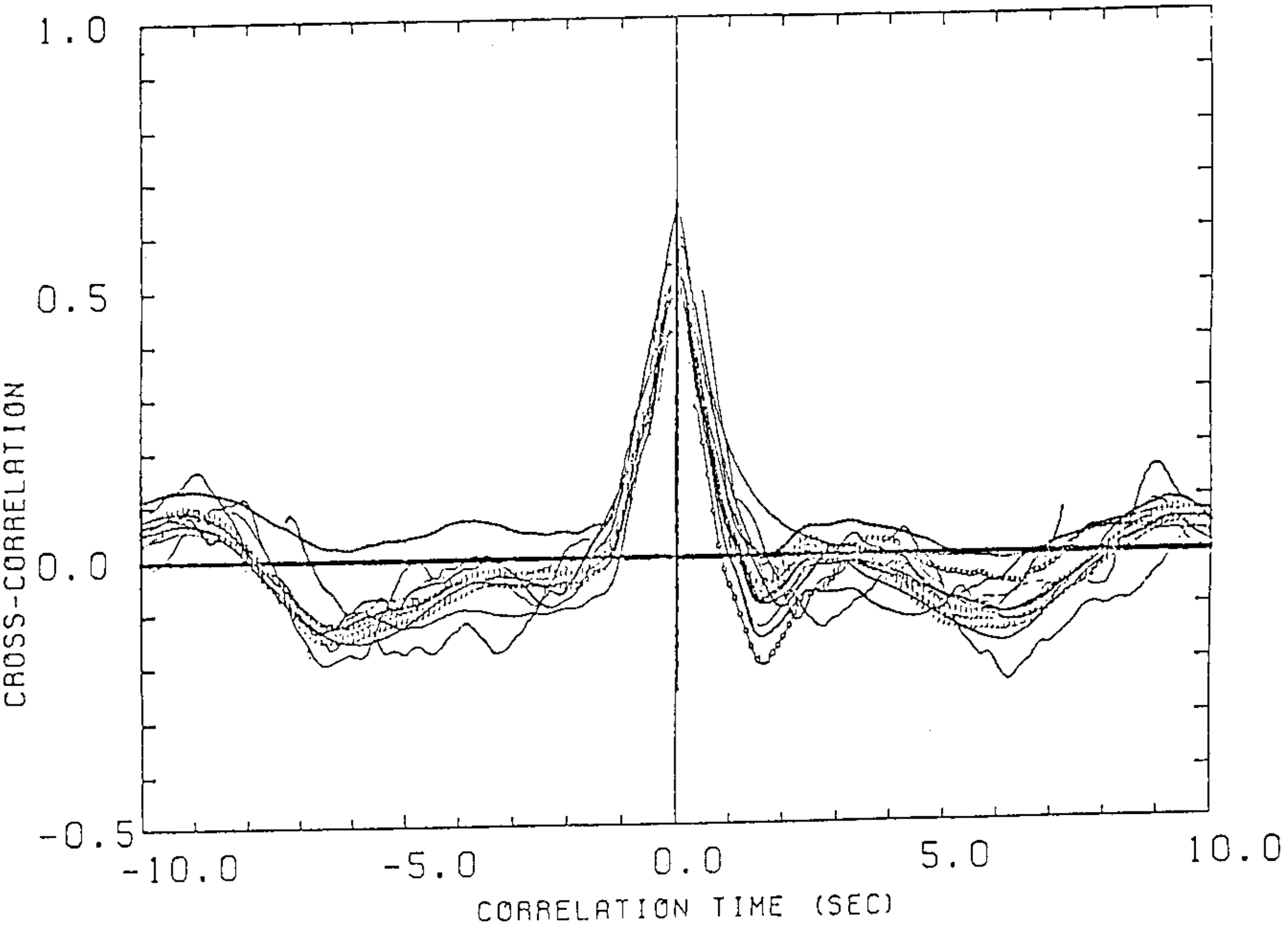


Fig. 17 C_{12} for Borssele noise data
computed by B,C,D,E,F,G,H,J,K,L,M,P,R,S,T,U

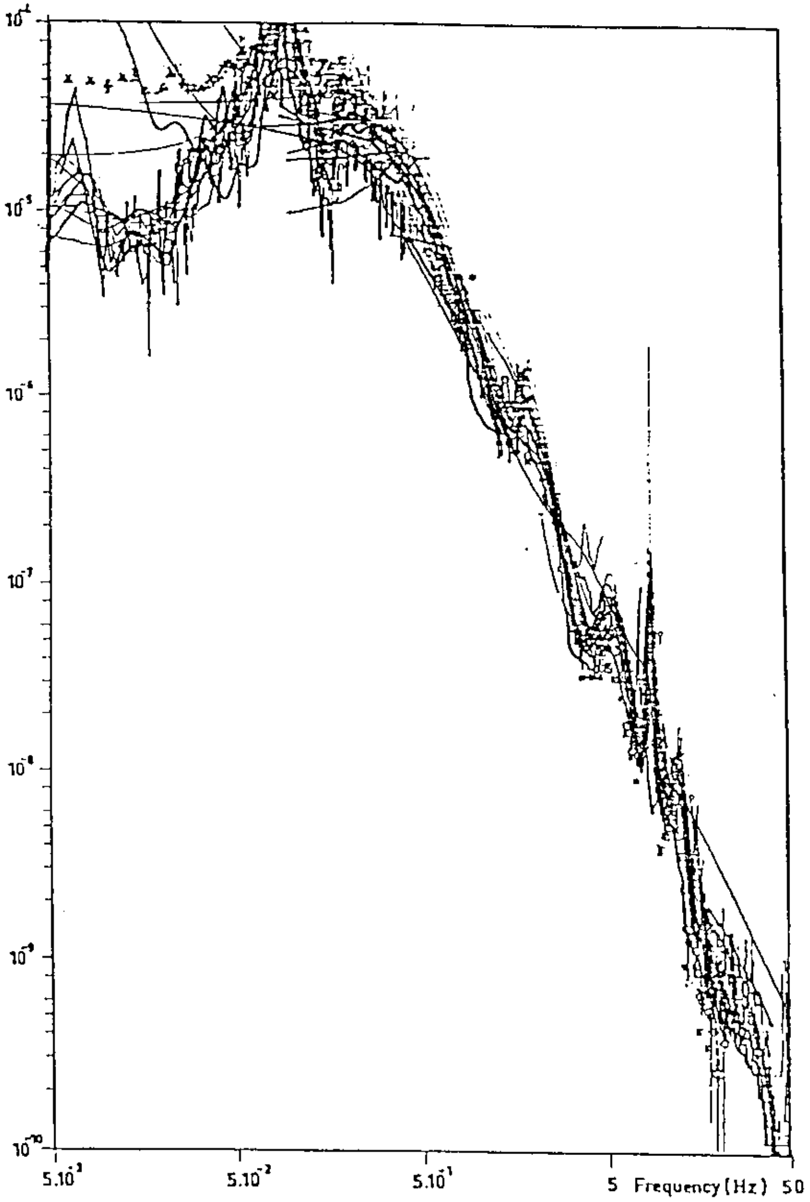


Fig. 18 P_{11} for Borssele noise data computed by A,B,C,D,E,F,G,H,J,K,L,M,N, O,P,Q,R,S,T,U,W

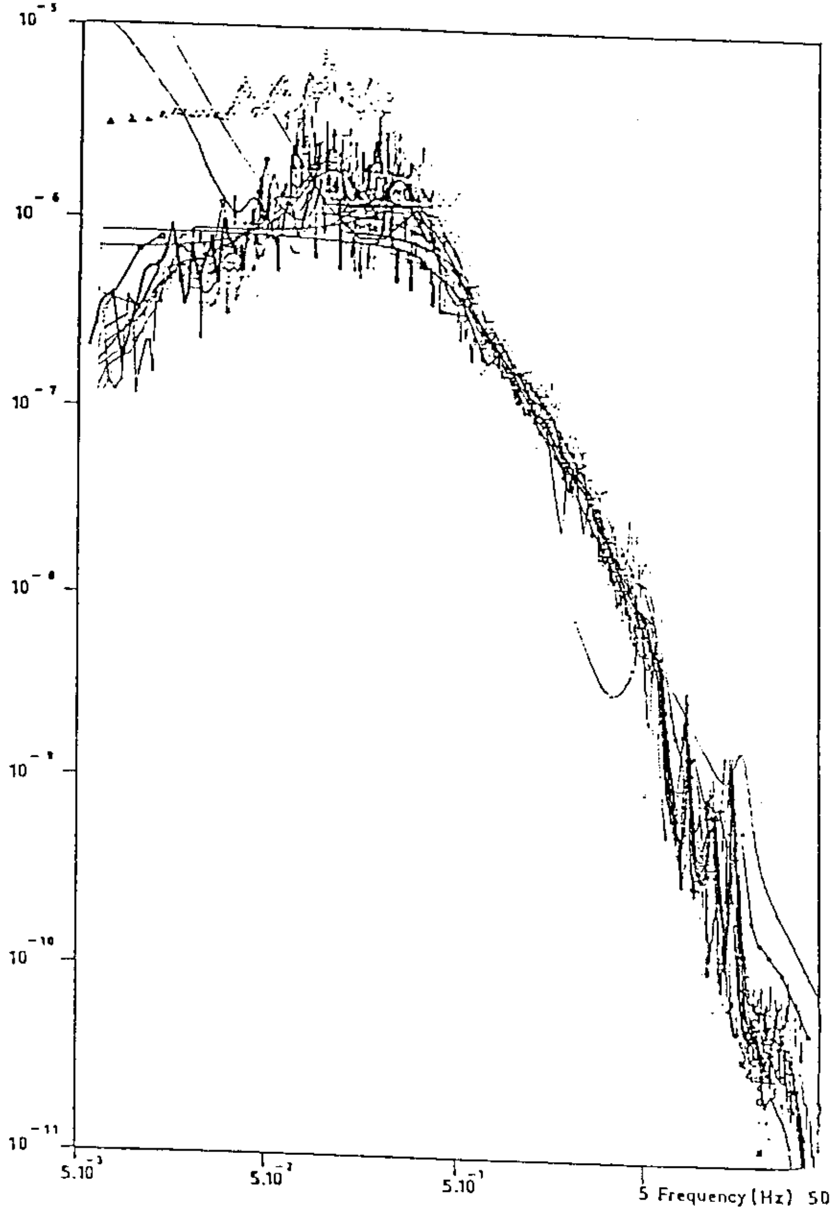


Fig. 19 P_{22} for Borssele noise data computed by A,B,C,D,E,F,G,H,J,K,L,M,N, O,P,Q,R,S,T,U,W

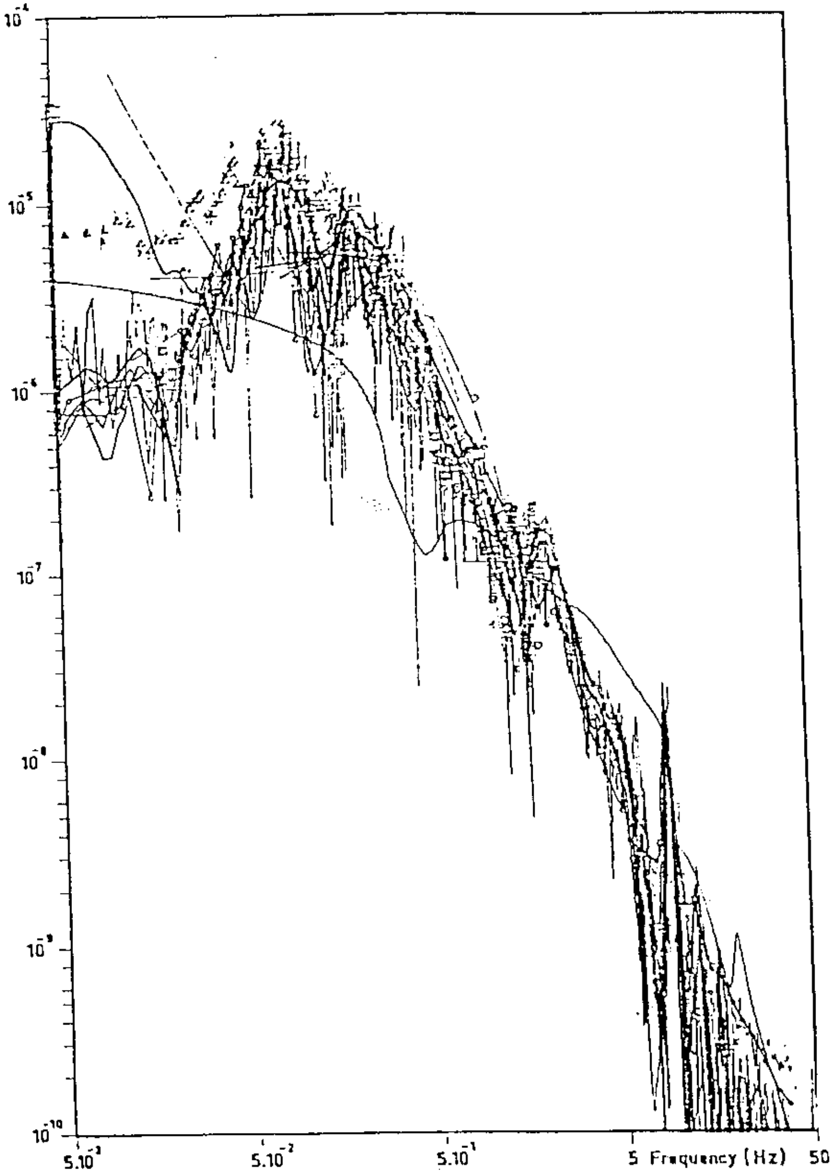


Fig. 20 P_{12} for Borssele noise data computed by B,C,D,E,F,G,H,I,J,K,L,M,N, P,Q,R,S,T,U

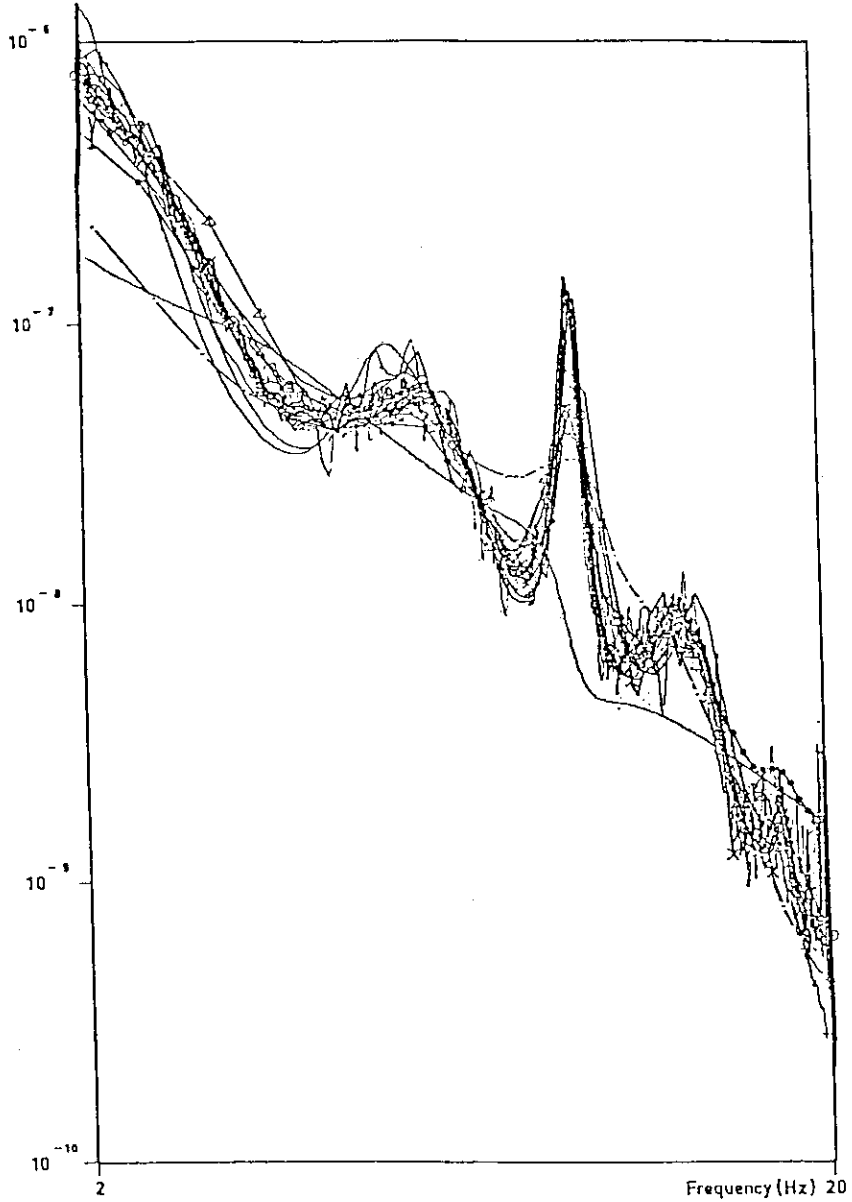


Fig. 21 P_{21} for Borssele noise data computed by A,B,C,D,E,F,G,H,J,K,N,O, Q,R,S,T,U,W

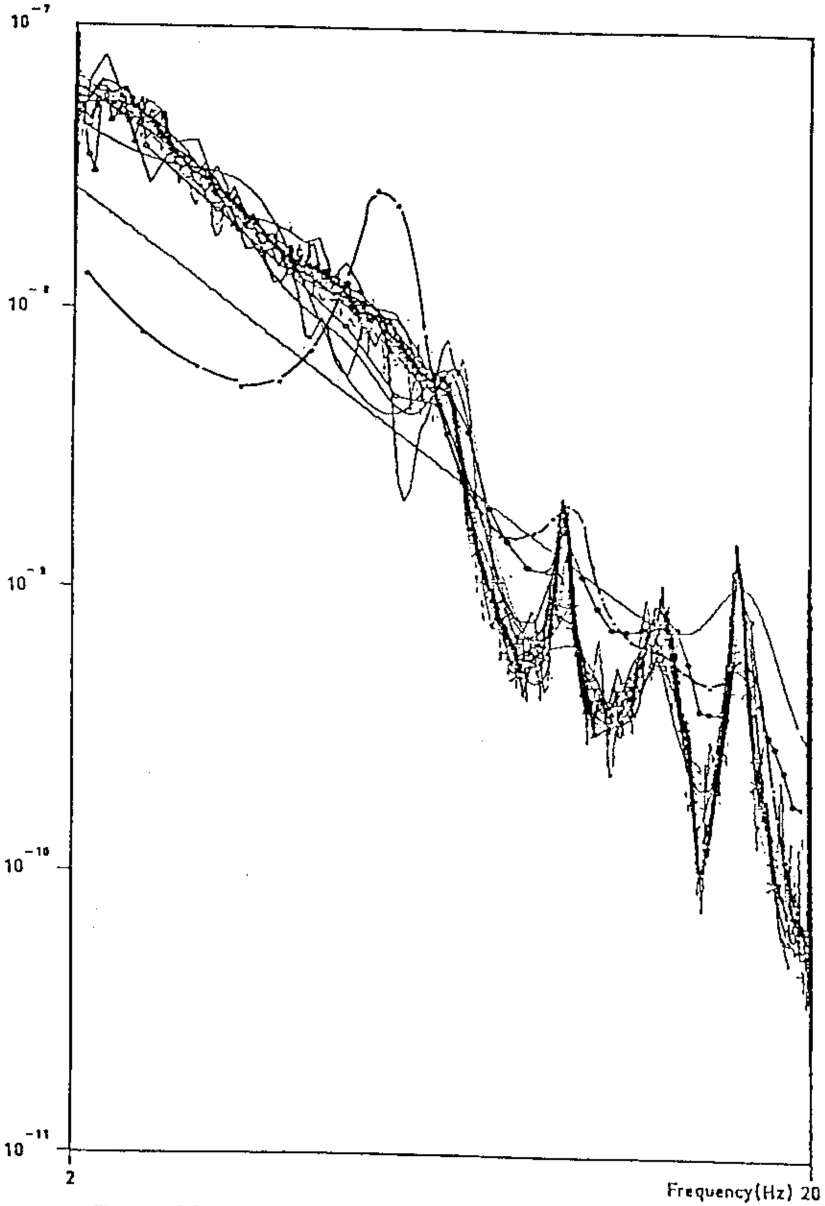


Fig. 22 P_{22} for Borssele noise data computed by B,C,D,E,F,G,H,J,K,N,O, Q,R,S,T,U,W

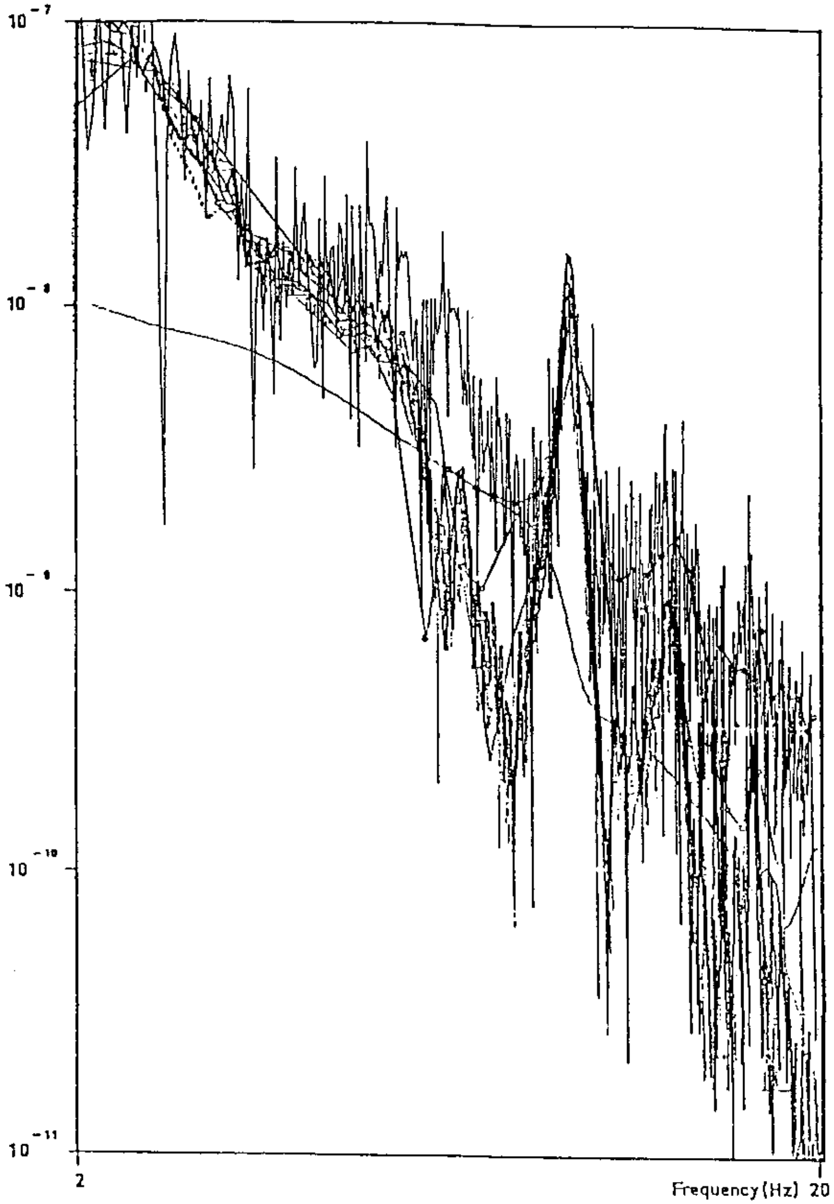


Fig. 23 P_{12} for Borssele noise data computed by B,C,D,E,F,H,J,K,N,Q,R,T,U,W

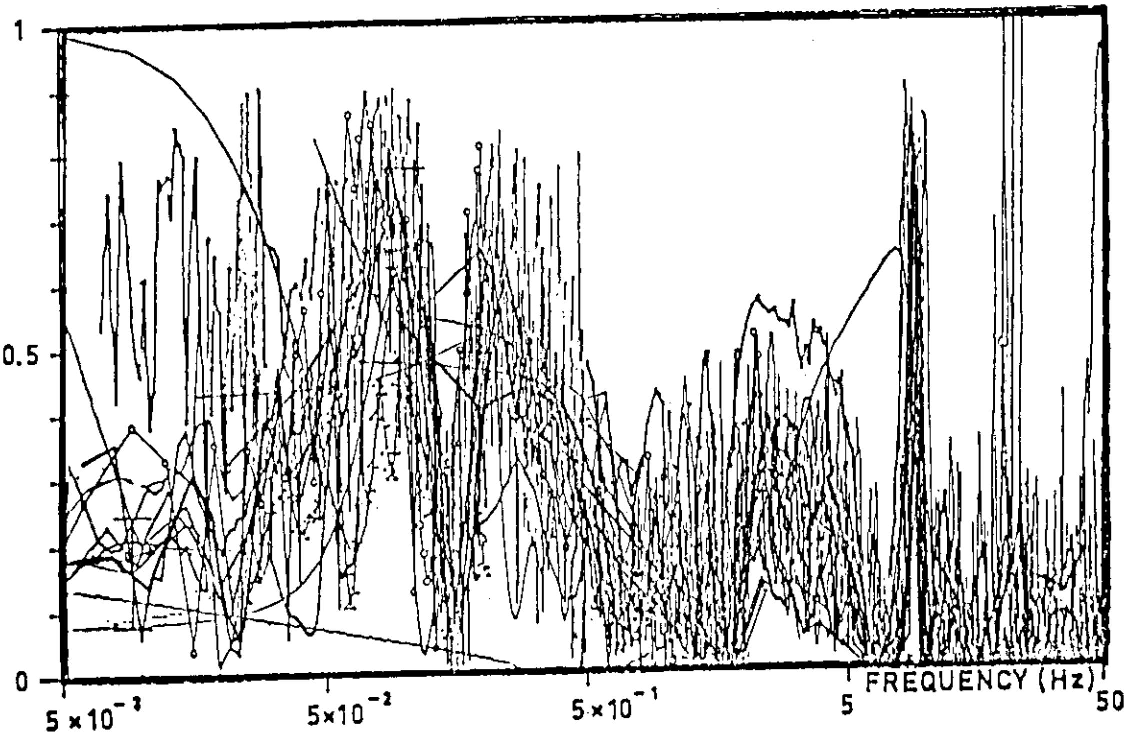


Fig.24 Coh for Borssele noise data
computed by B,C,D,E,F,G,H,I,J,K,L,M,N,P,Q,R,S,T,U

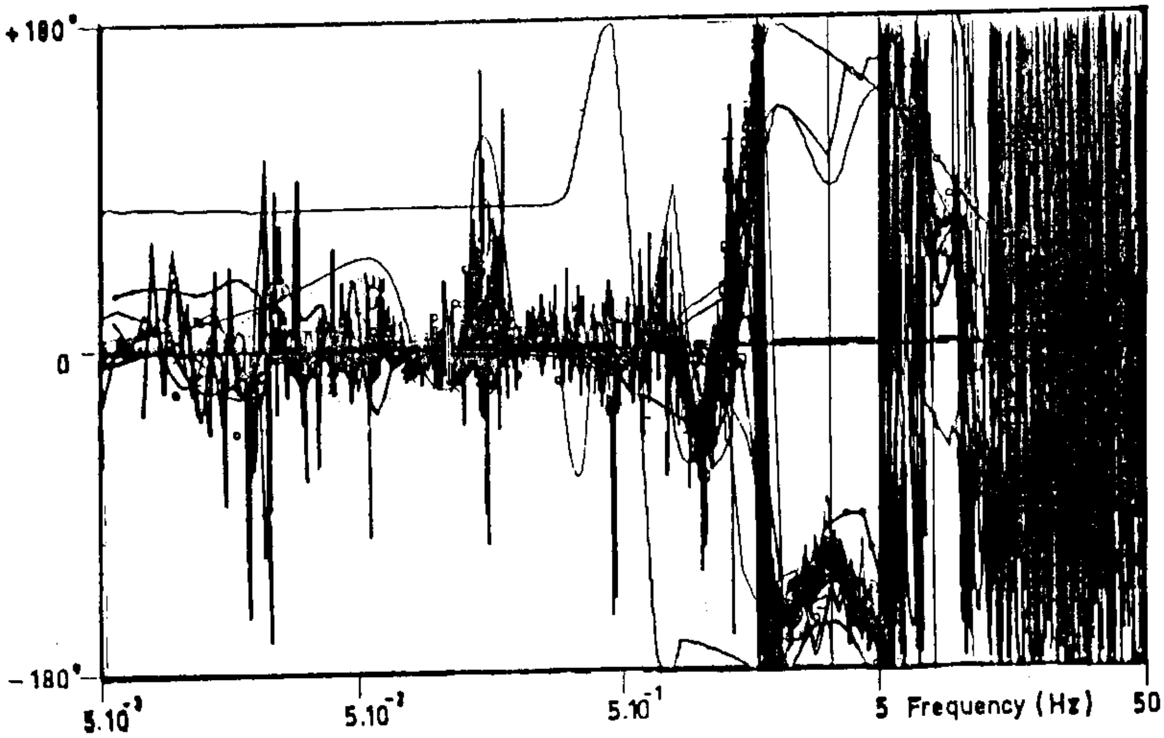


Fig.25 Ph for Borssele noise data
computed by B,C,D,E,F,G,H,I,J,K,L,M,N,P,Q,R,S,T,U

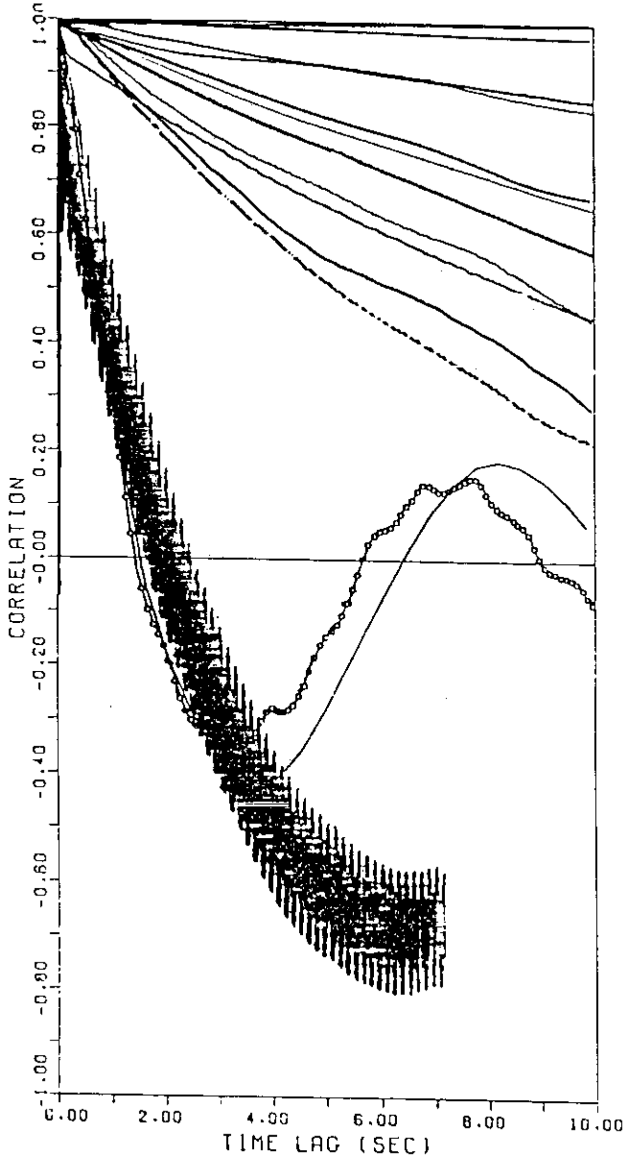


Fig. 26 C_{11} for Phenix reactor noise data computed by B,C,D,E,F,H,J,K,P,S,T,W,

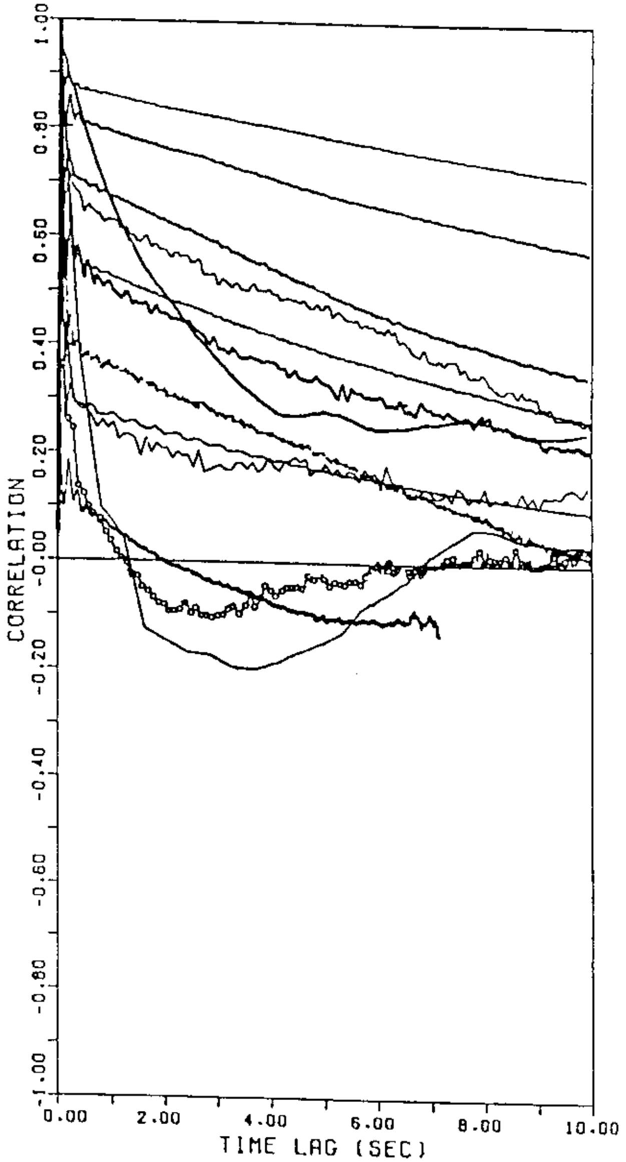


Fig. 27 C_{55} for Phenix reactor noise data computed by B,C,D,E,F,H,J,K,P,S,T,W

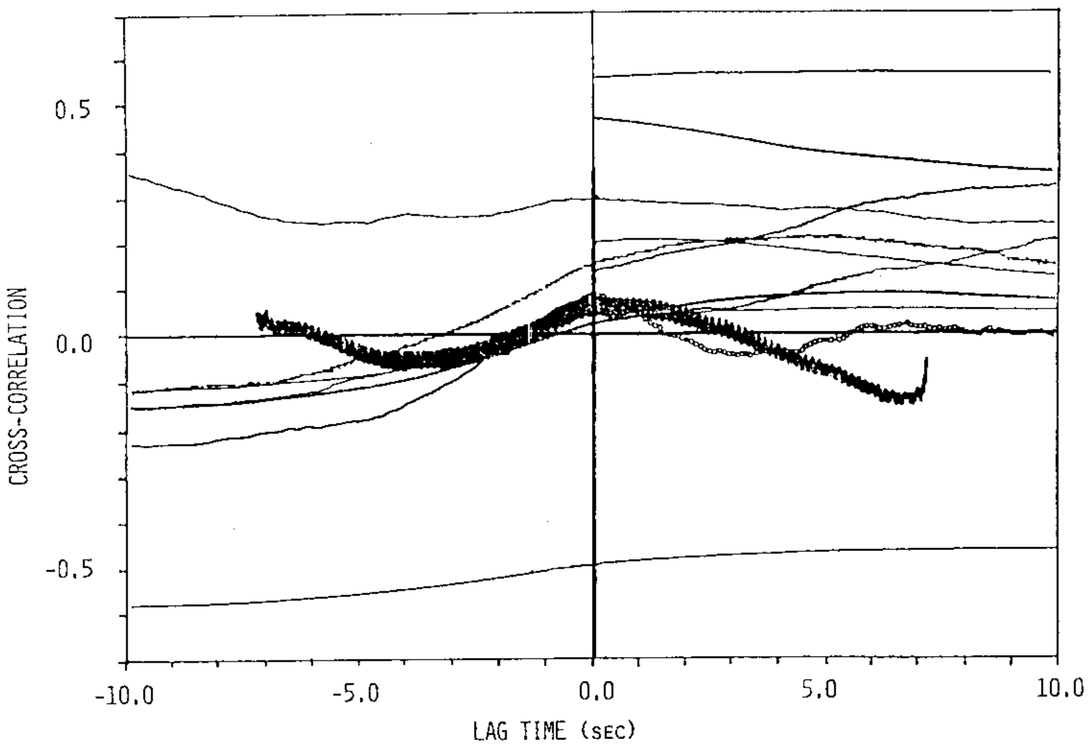


Fig. 28 C_{15} for Phenix reactor noise data computed by B,C,D,E,F,H,J,K,R,S,T

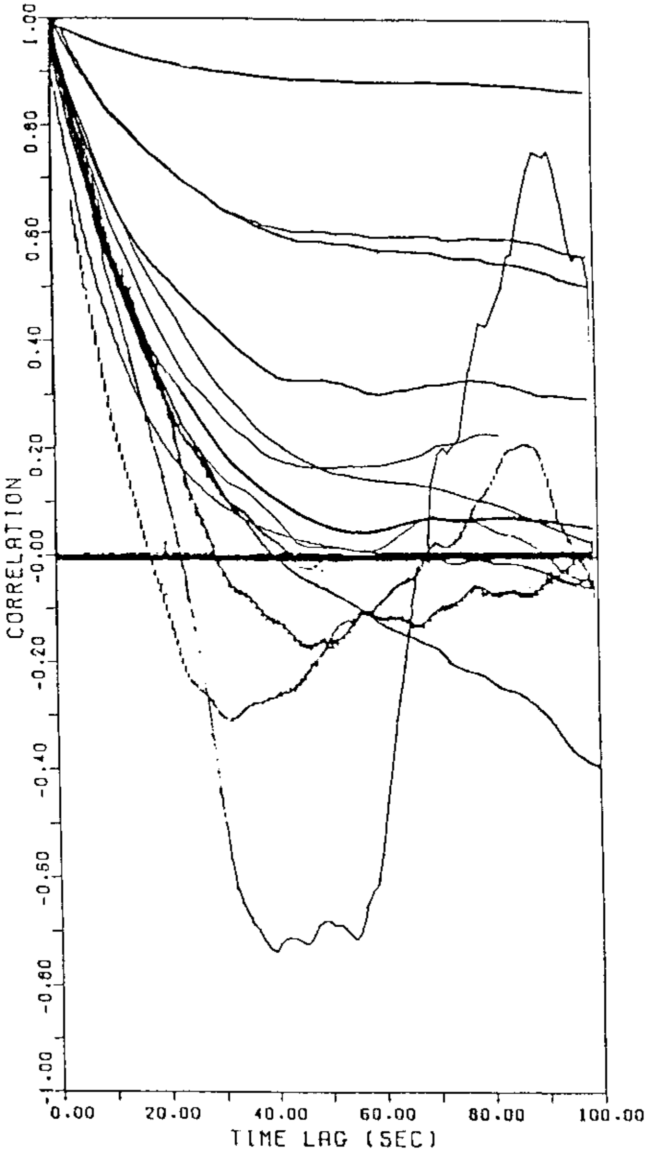


Fig. 29 C_{11} for Phenix reactor noise data computed by B,C,D,E,F,G,I,J,K,M, P,R,T,U

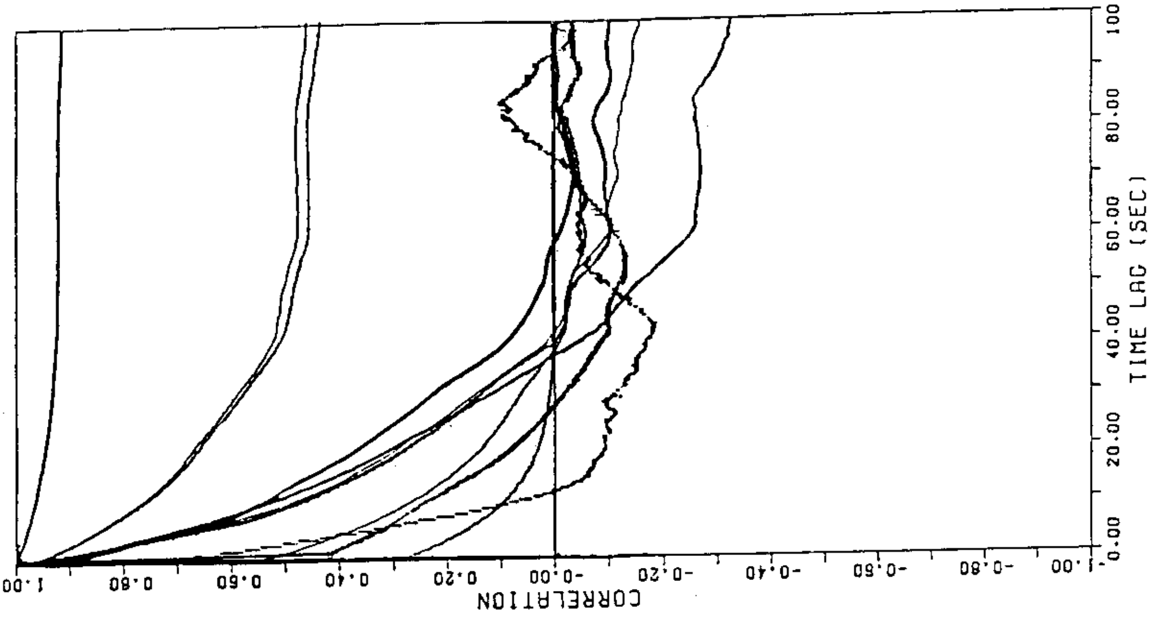


Fig. 30 C_{55} for Phenix reactor noise data computed by B,C,D,F,G,I,J,K,M,T,U

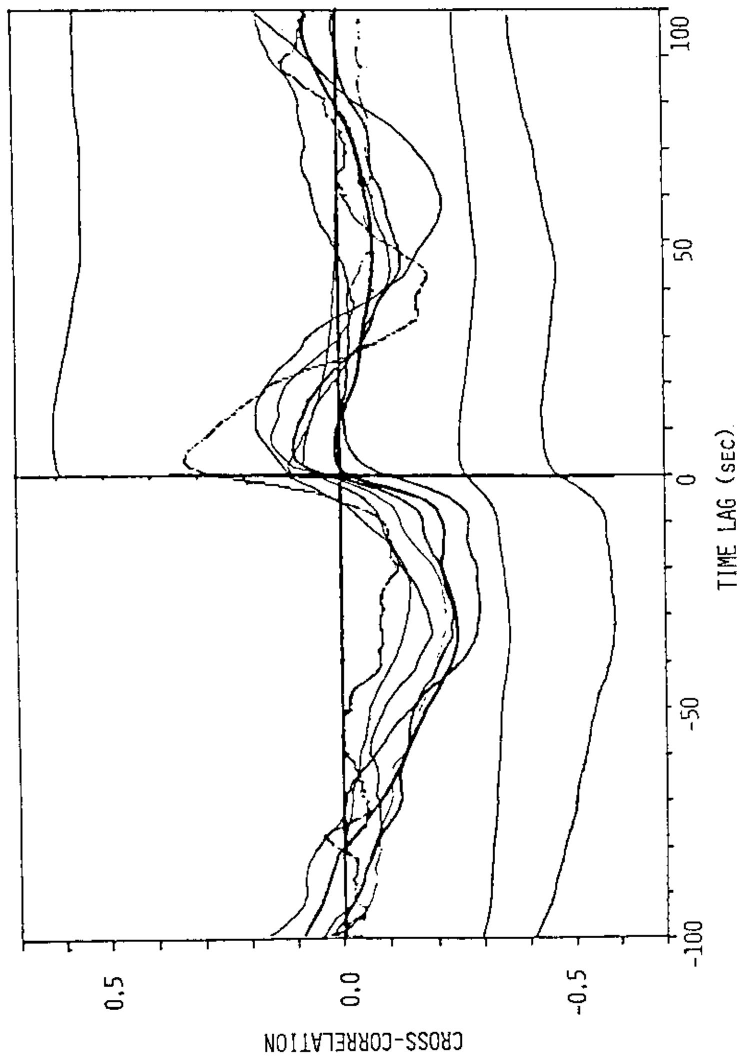


Fig. 31 C_{15} for Phenix reactor noise data computed by B,C,D,F,G,I,J,K,M,T,U

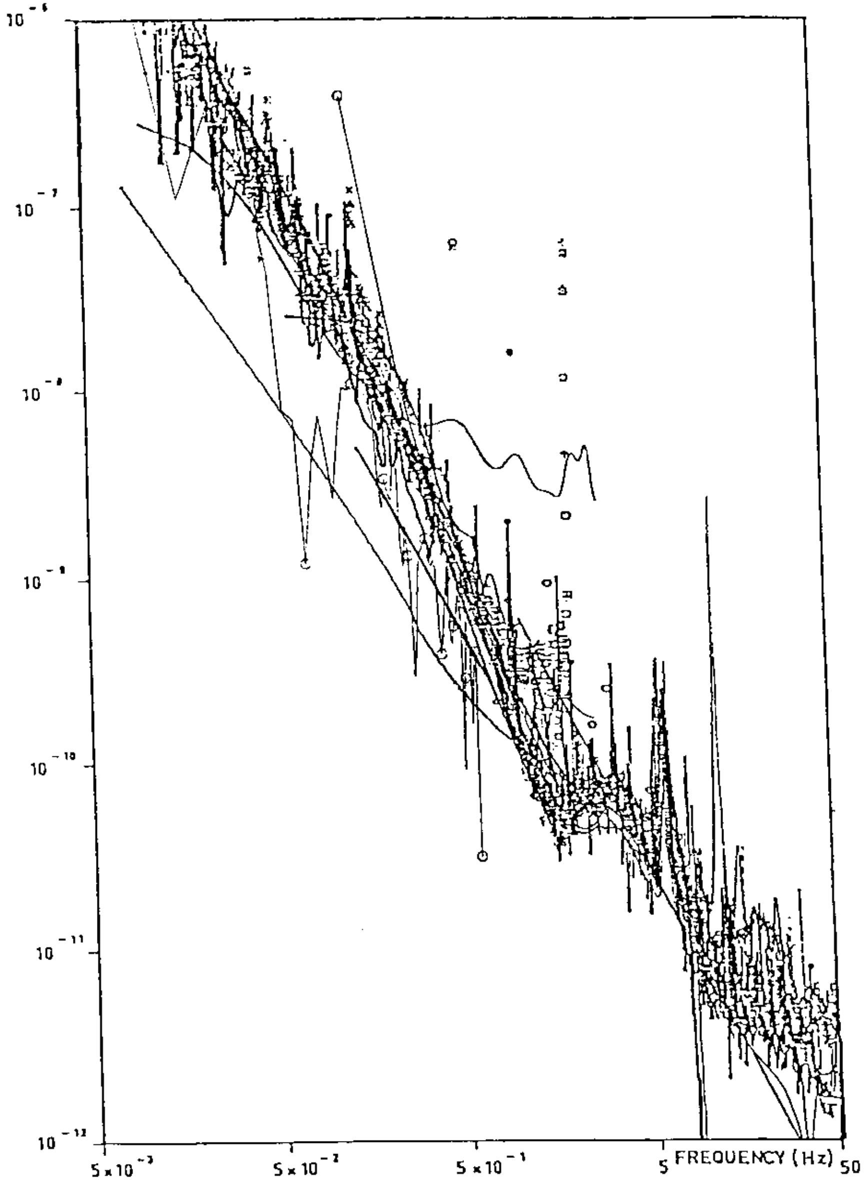


Fig. 32 P_{11} for Phenix reactor noise data computed by A,B,C,D,E,F,G,H,I,J,K, M,N,O,P,Q,R,S,T,U

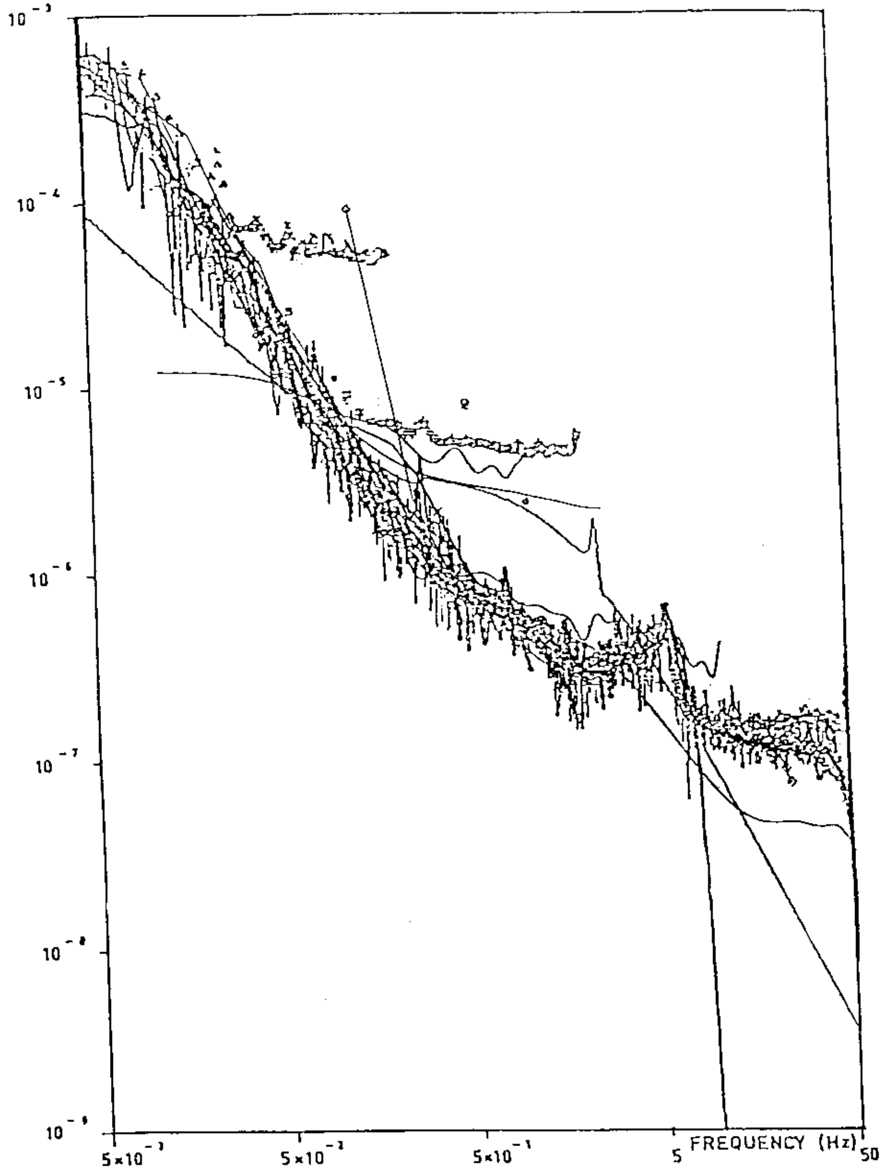


Fig. 33 P_{55} for Phenix reactor noise data computed by A,B,C,D,E,F,G,H,I,J,K, M,N,O,Q,R,S,T,U

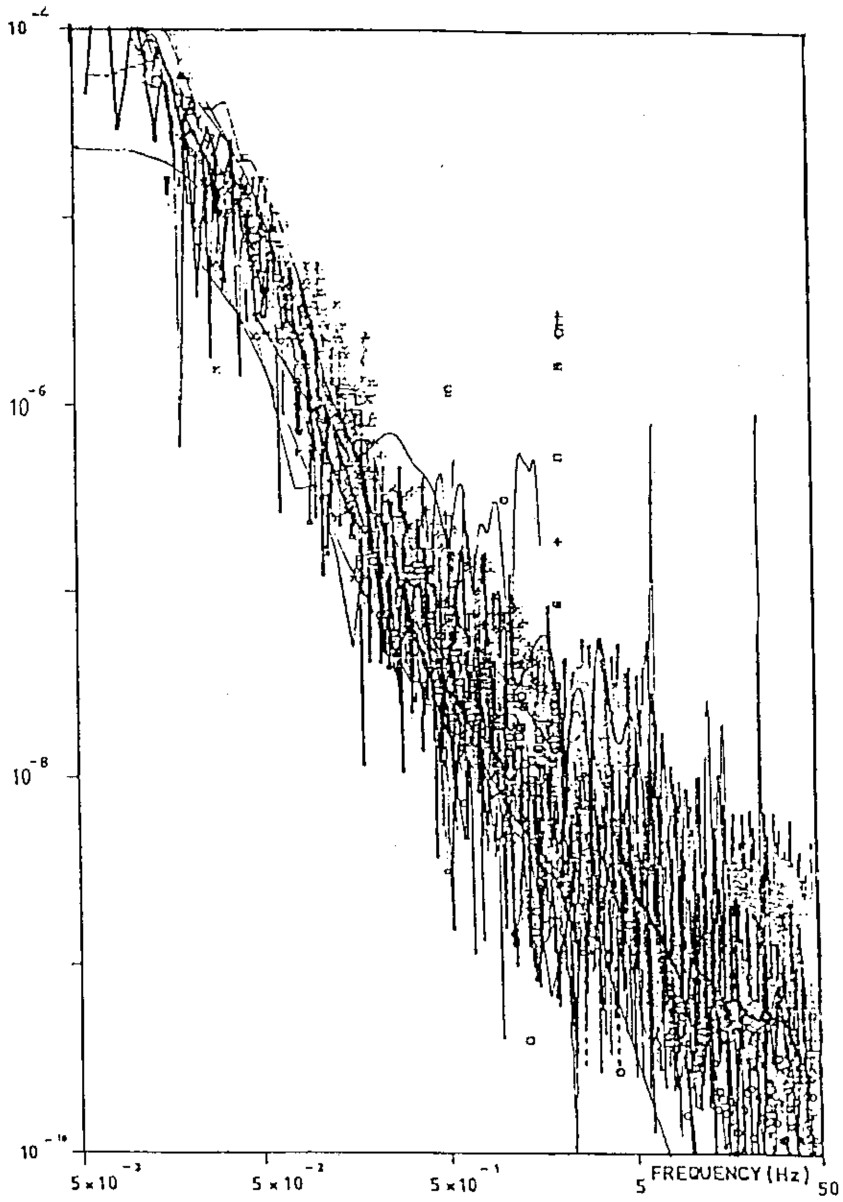


Fig. 34 P_{15} for Phenix reactor noise data computed by B,C,D,E,F,G,H,I,J,K,M, N,Q,R,S,T,U

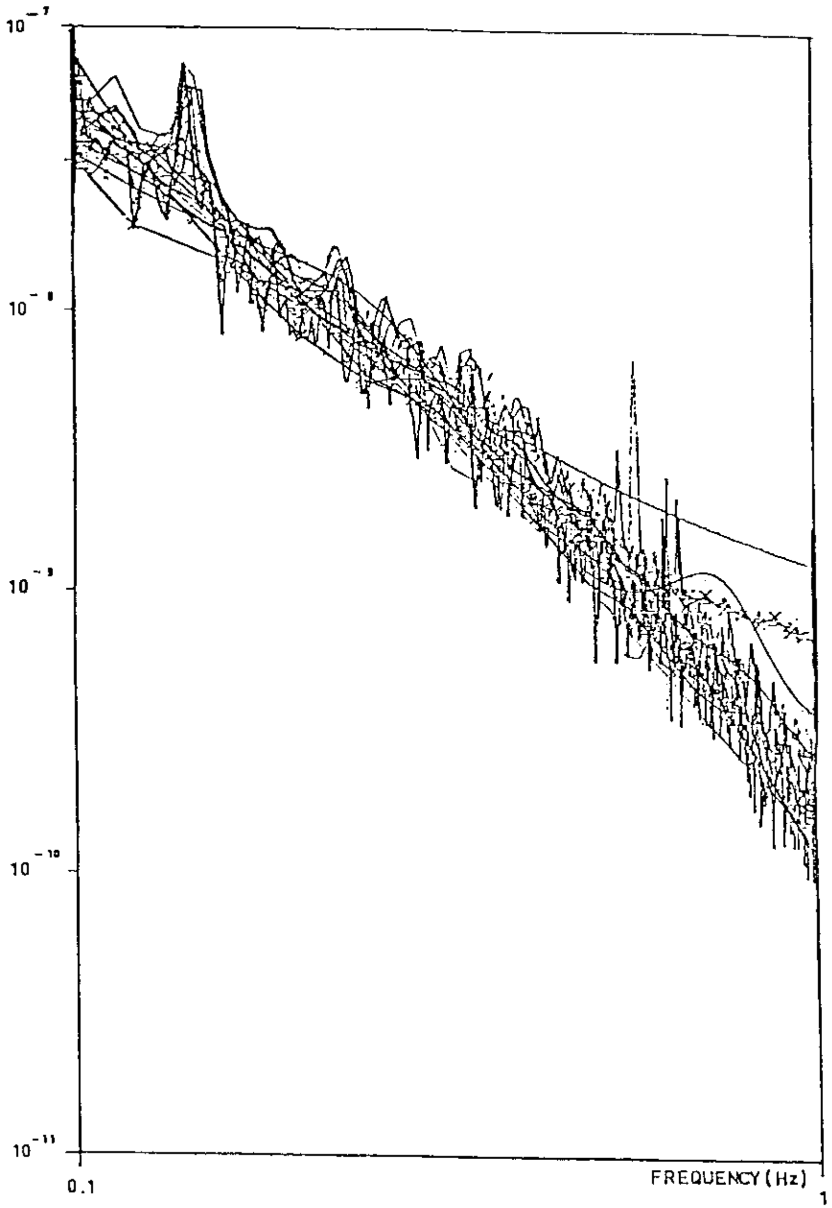


Fig. 35 P_{11} for Phenix reactor noise data computed by A,B,C,D,E,F,G,H,J,K,N,O, Q,R,S,T,U,W

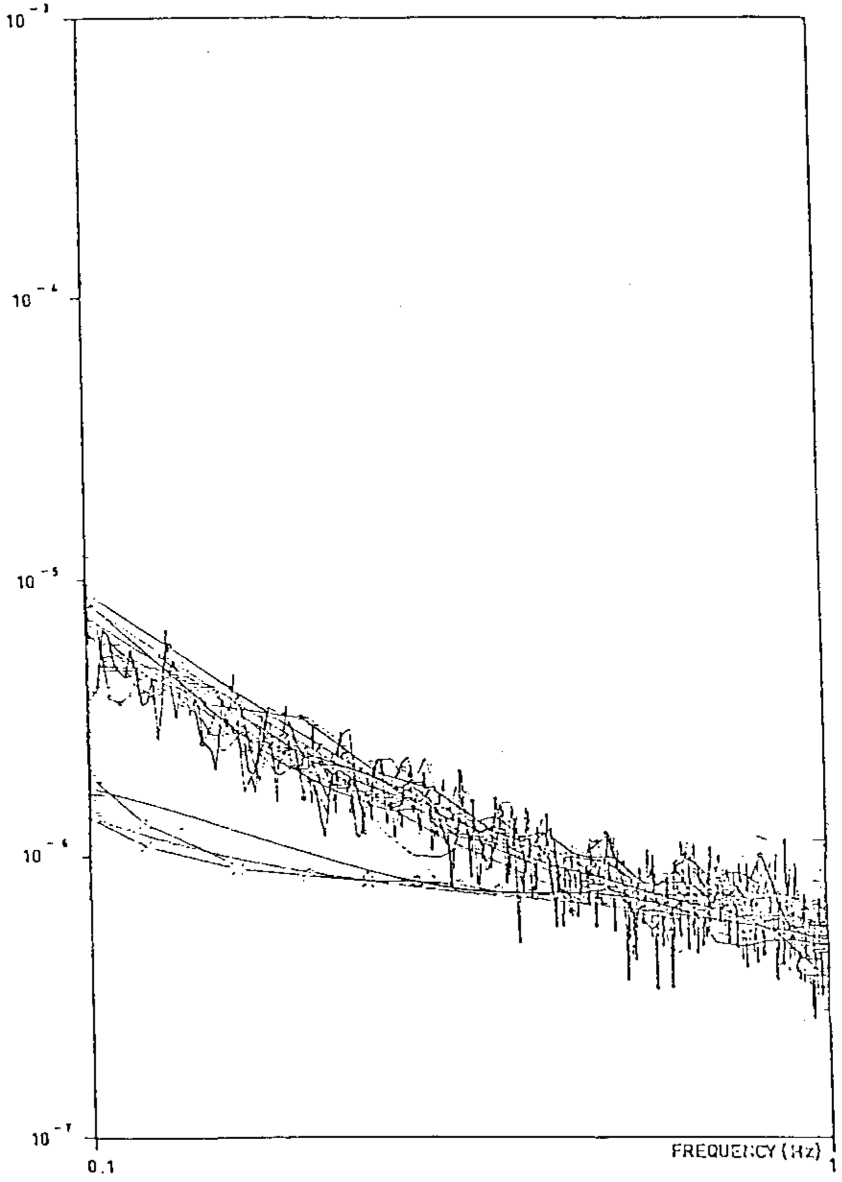


Fig. 36 P_{55} for Phenix reactor noise data computed by A,B,C,D,E,F,G,H,J,K,N,O, Q,R,S,T,U,W

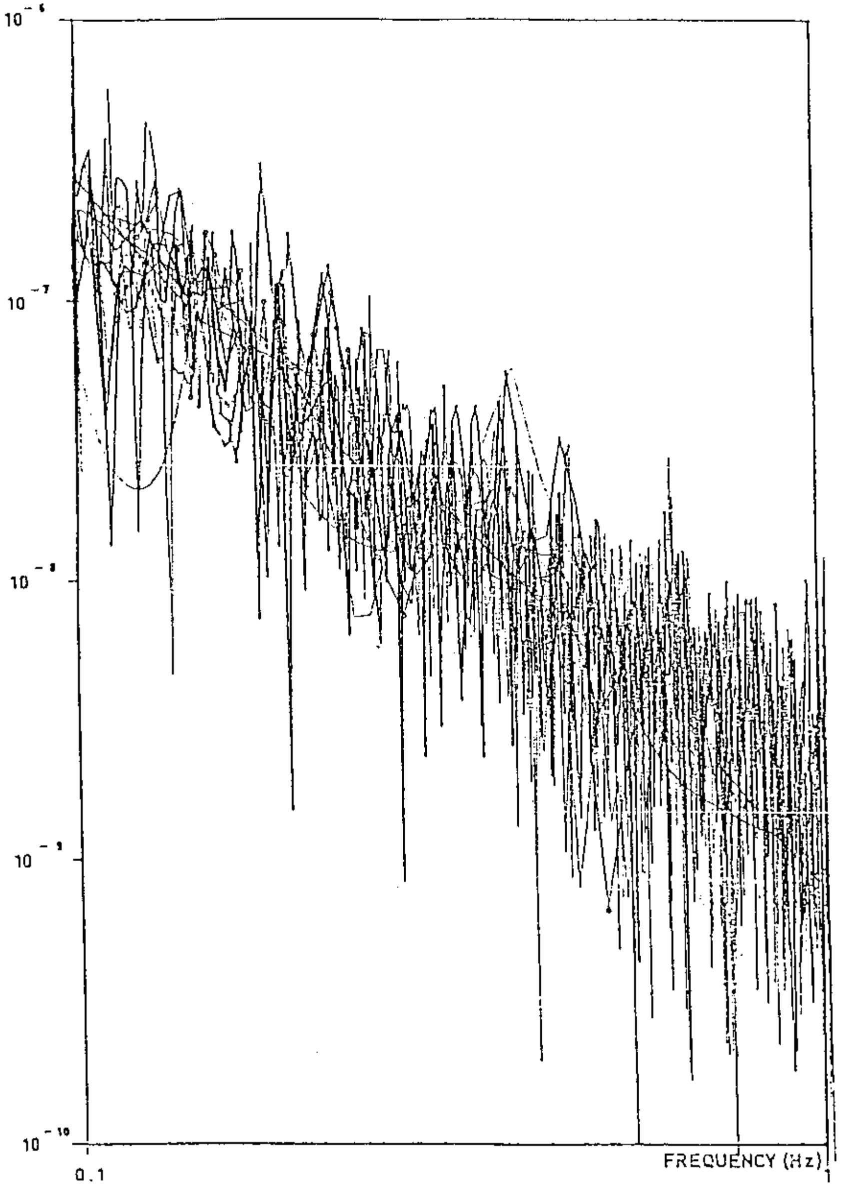


Fig. 37 P_{15} for Phenix reactor noise data computed by B,C,D,E,F,H,J,K,N,Q,R,T,U,W

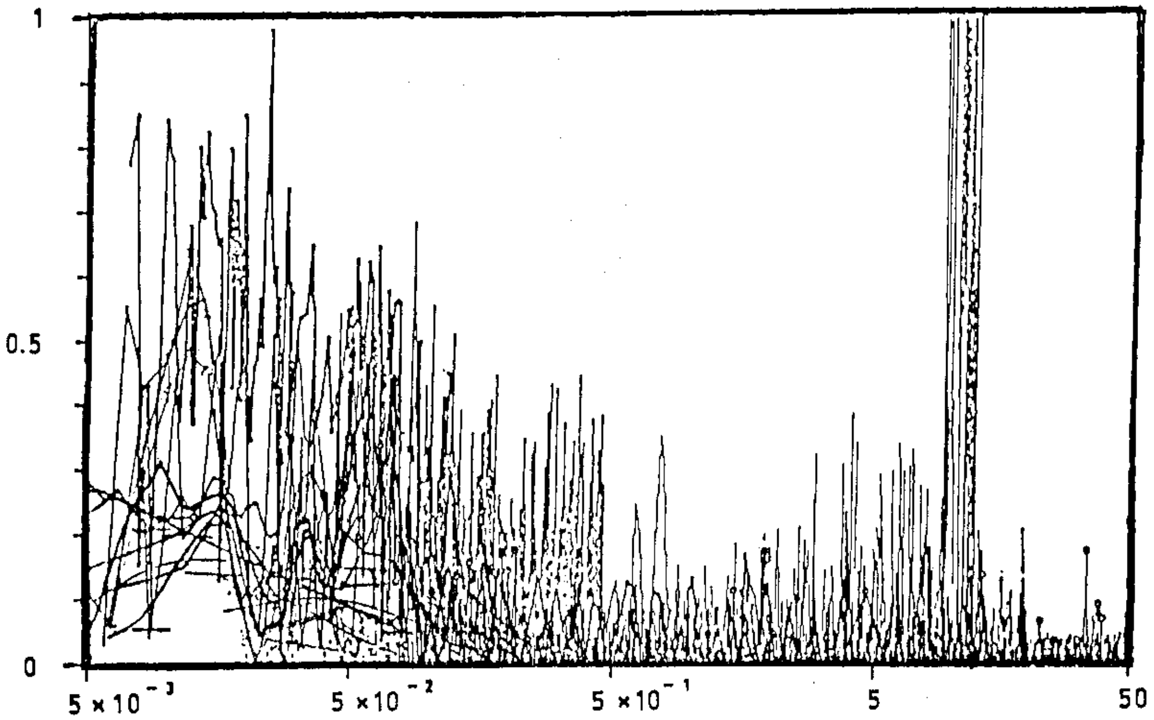


Fig.38 Coh for Phenix reactor noise data
computed by B,C,D,E,F,G,H,I,J,K,M,N,Q,R,S,T,U

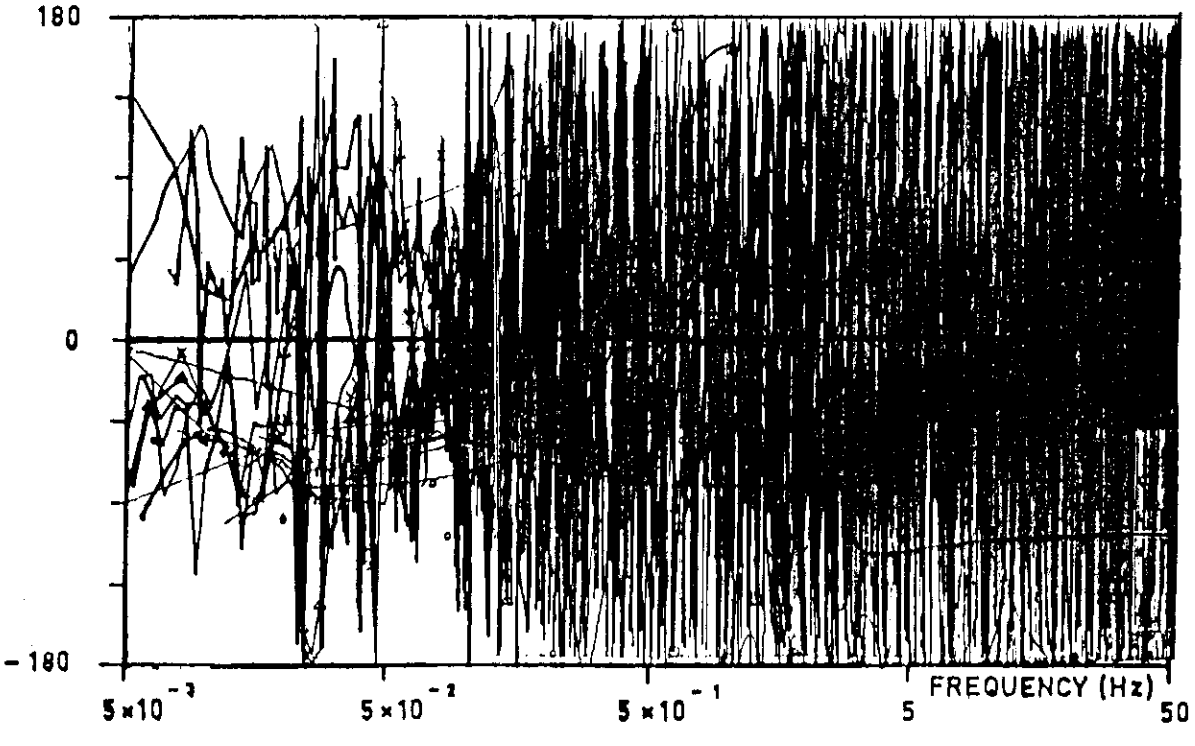


Fig.39 Ph for Phenix reactor noise data
computed by B,C,D,E,F,G,H,I,J,K,M,N,Q,R,S,T,U

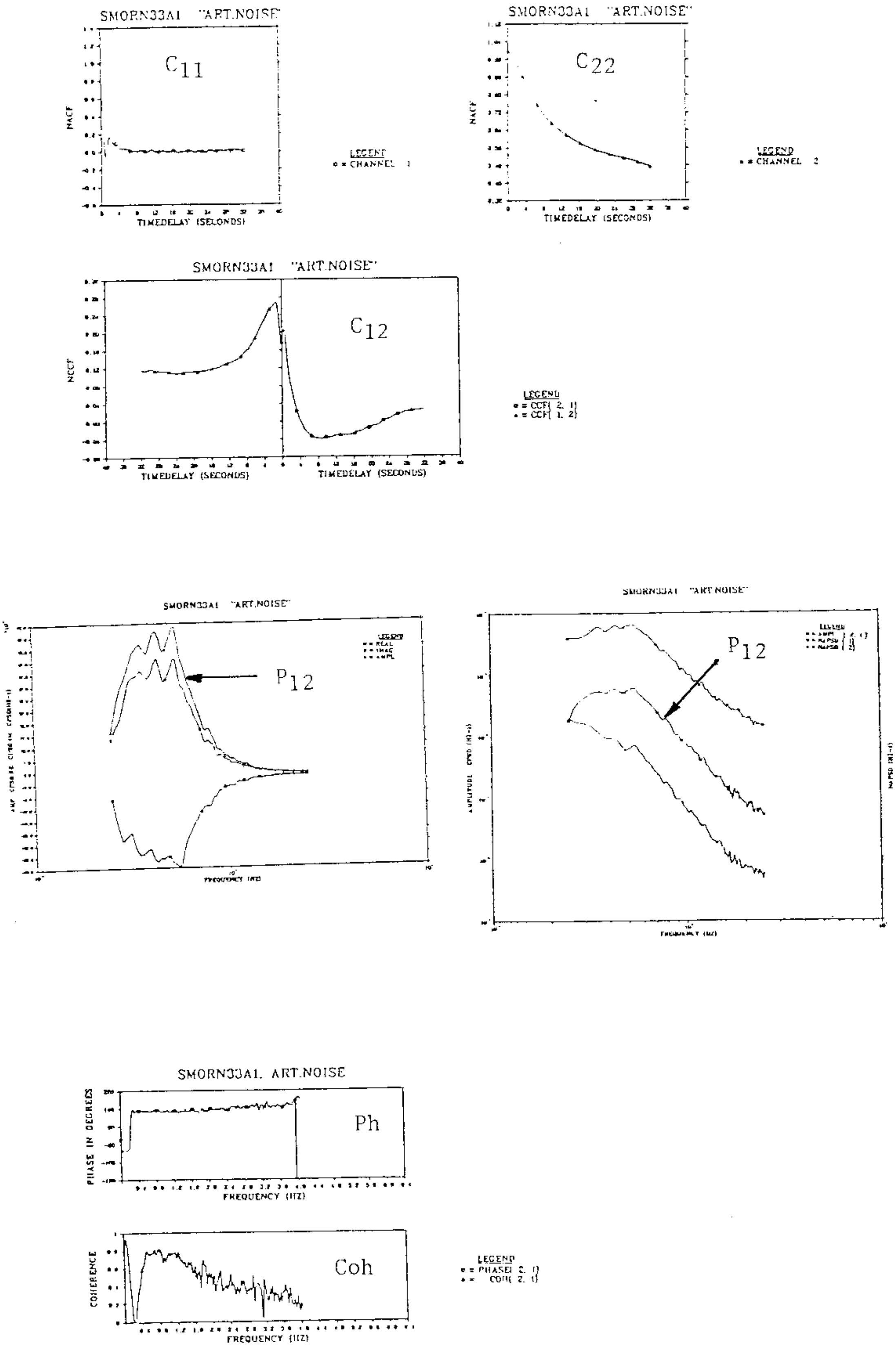
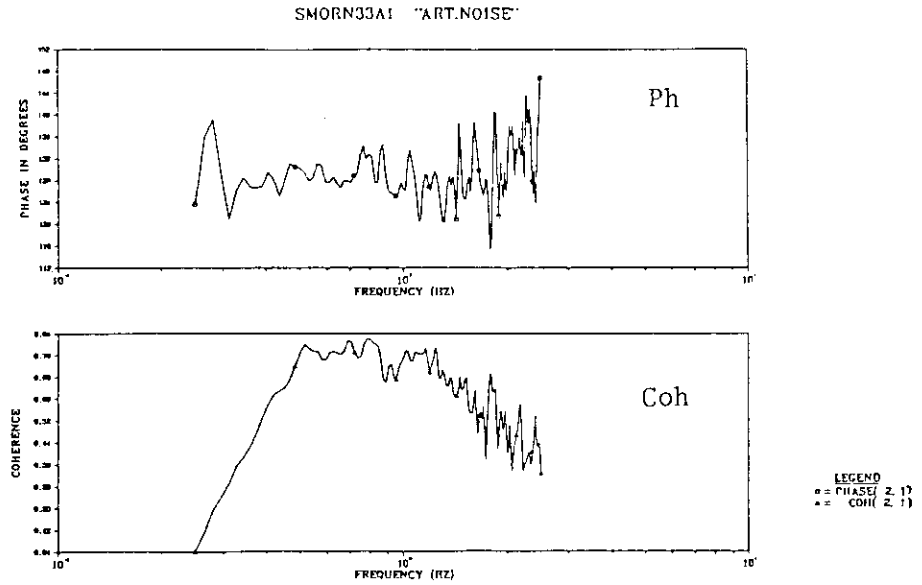
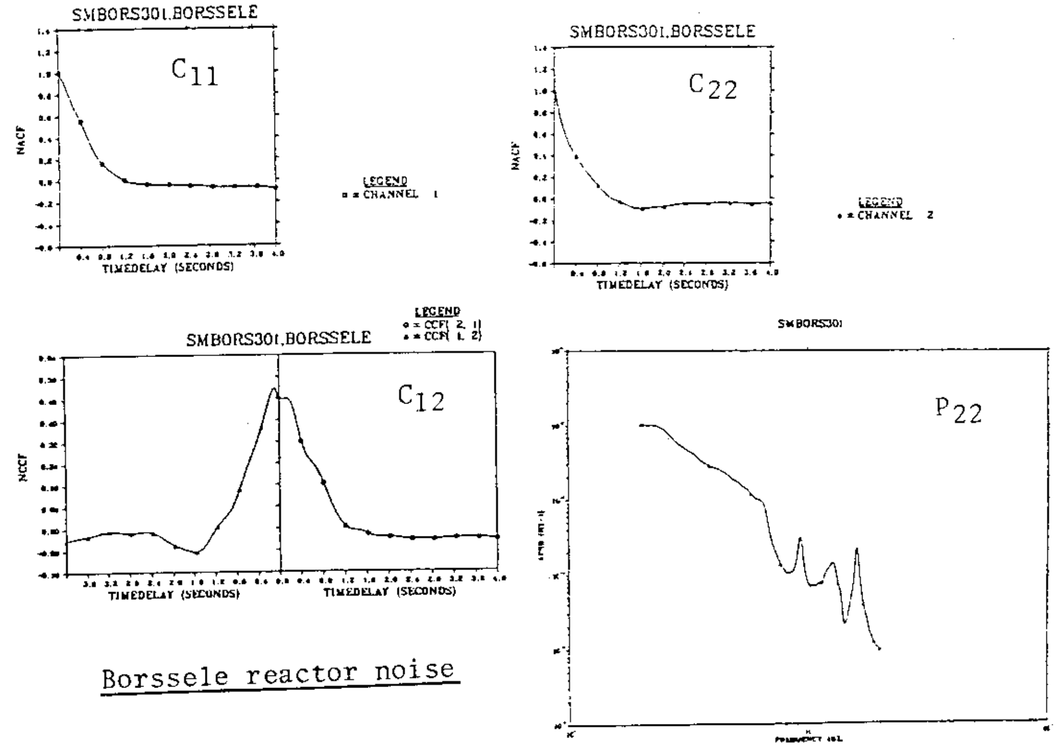


Fig.40 Functions computed by A

Artificial noise

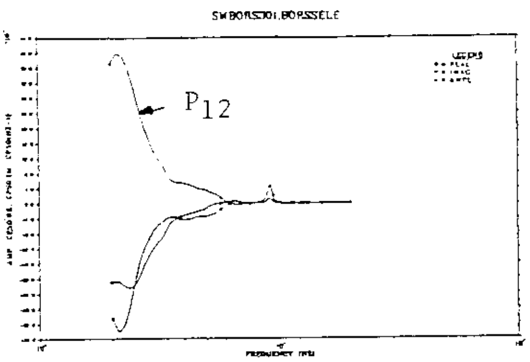


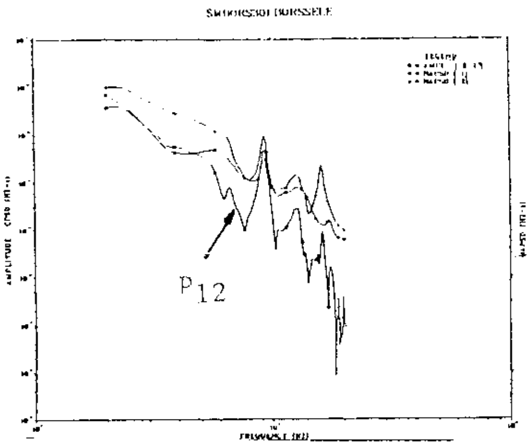
Artificial noise

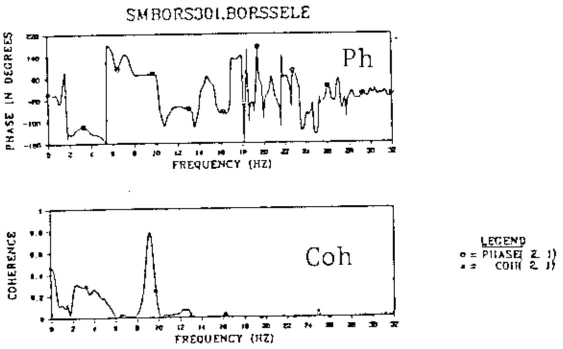


Borssele reactor noise

Fig.40 Functions computed by A (continued)







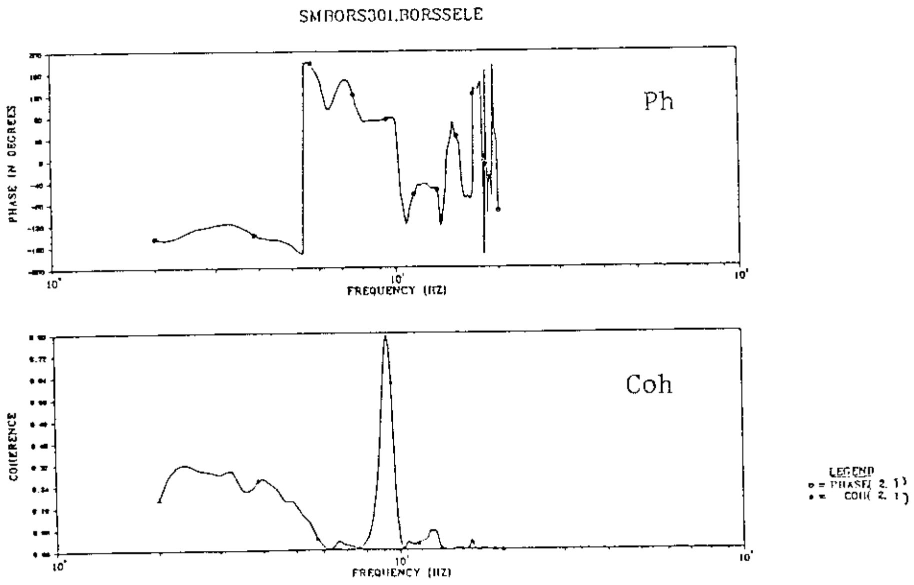


Fig.40 Functions computed by A (continued)

<u>Borssele reactor noise</u>

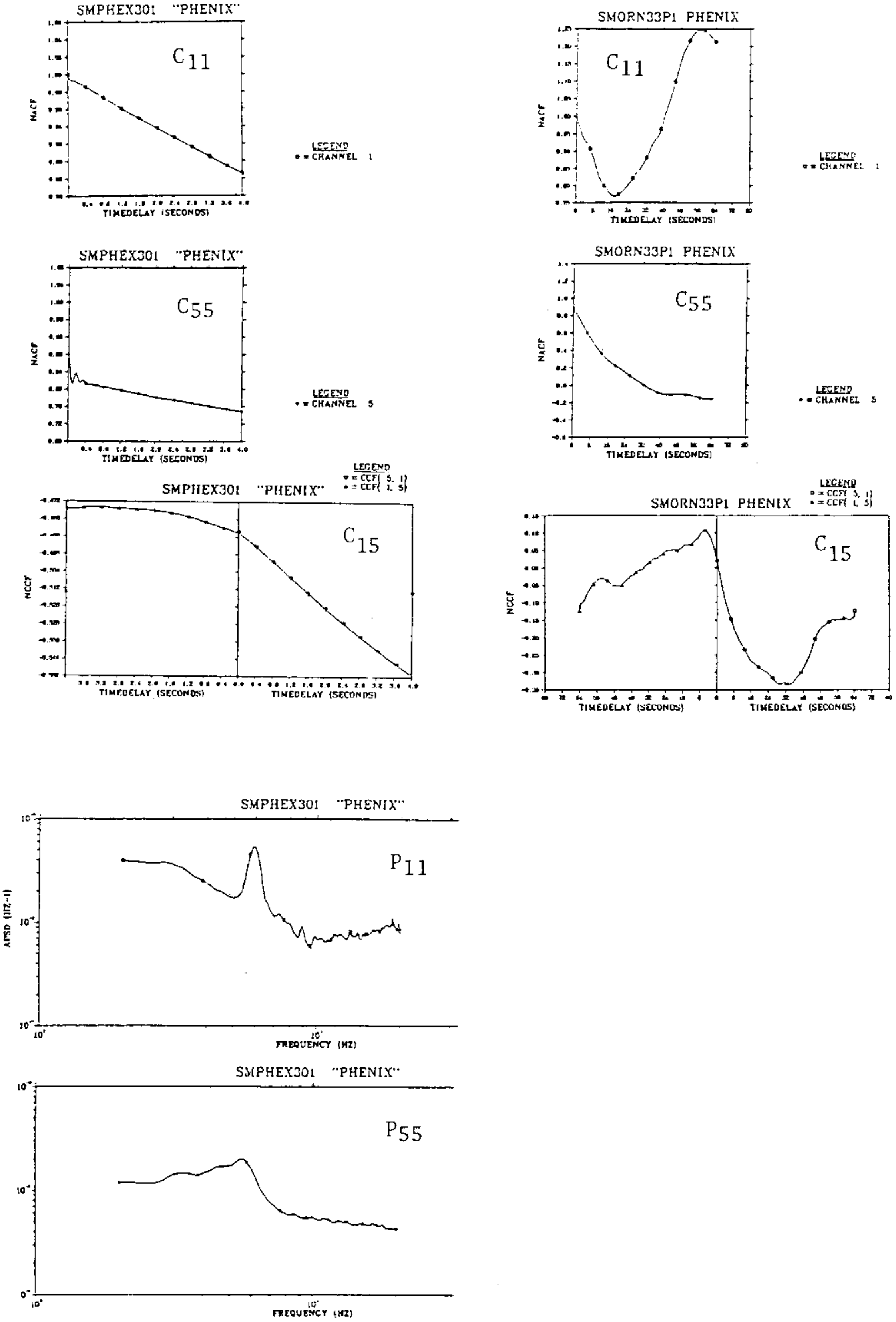


Fig.40 Functions computed by A (continued)

Phenix reactor noise

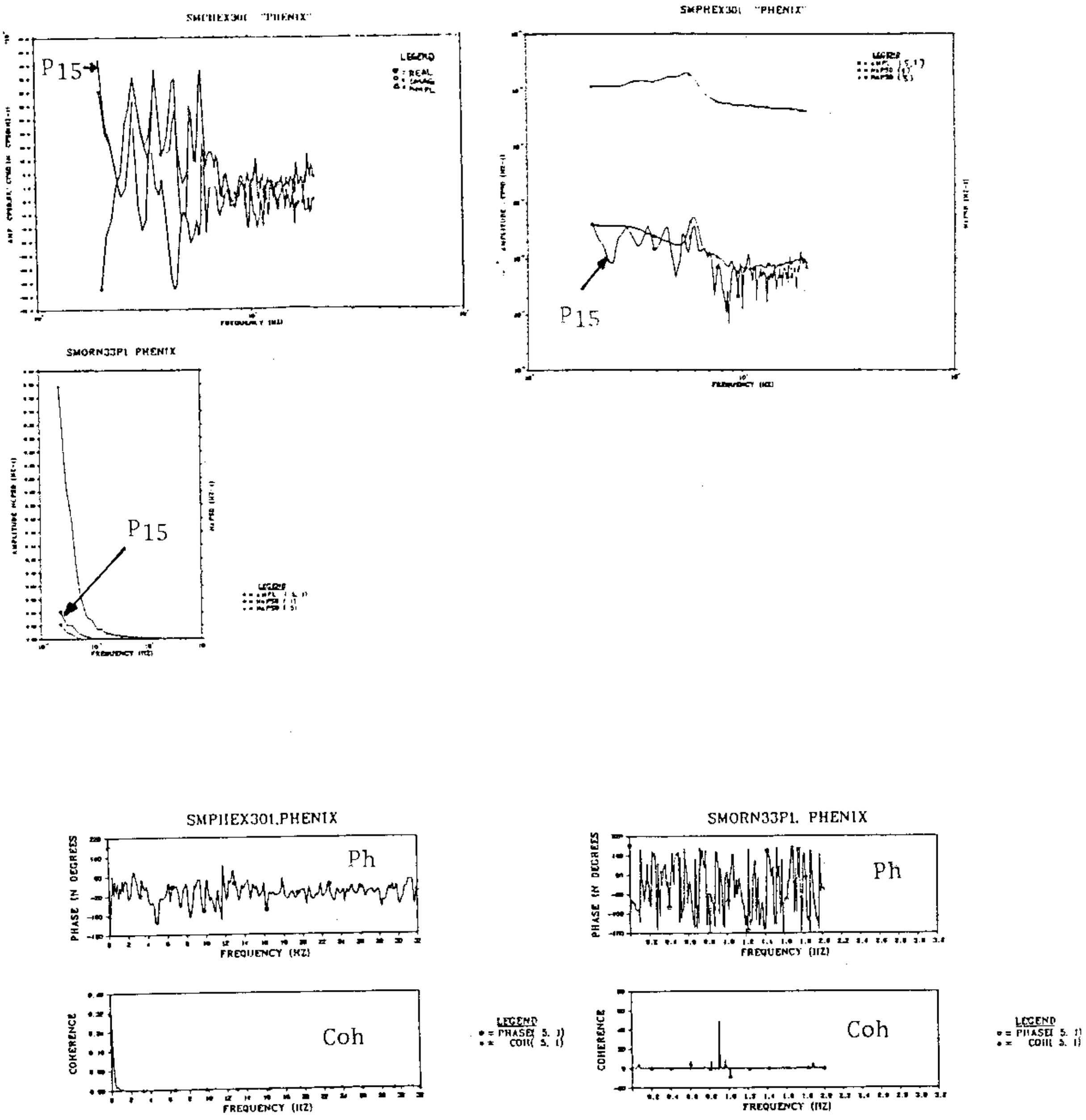


Fig.40 Functions computed by A (continued)

Phenix reactor noise

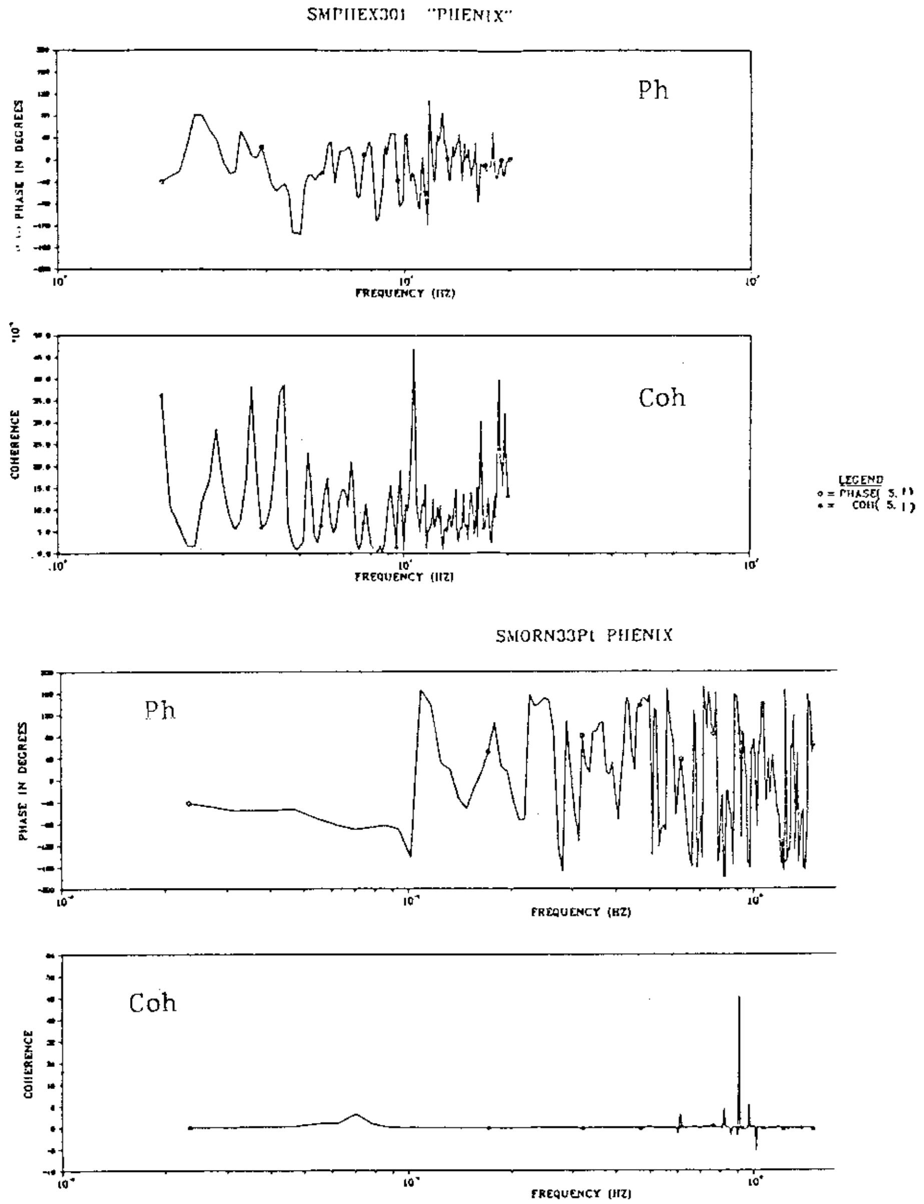
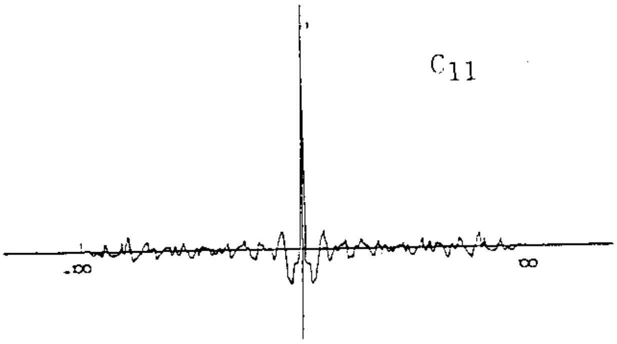
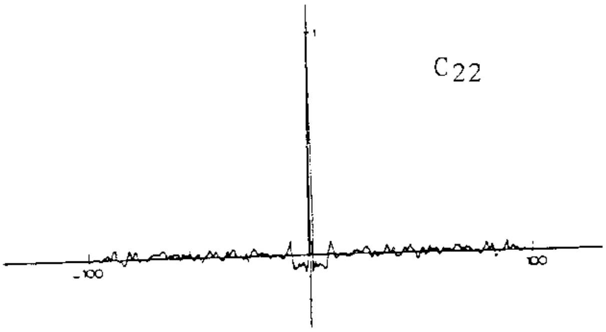


Fig.40 Functions computed by A (continued)

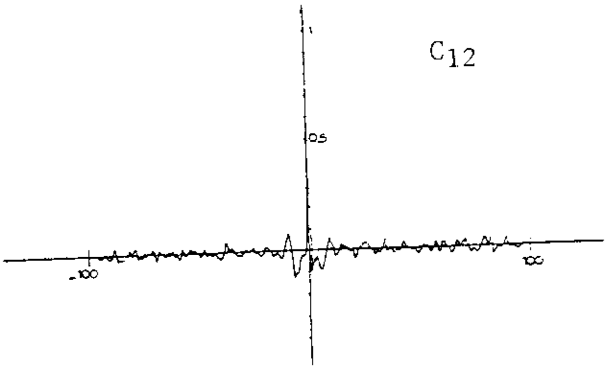
Phenix reactor noise



BORSSELE AUTO CORRELATION : IN 12



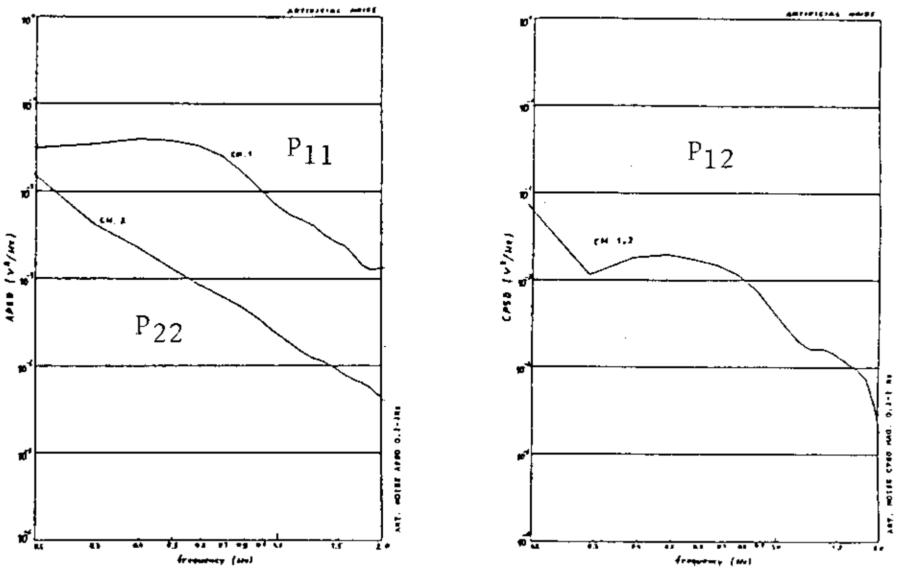
BORSSELE AUTO CORRELATION : LOG



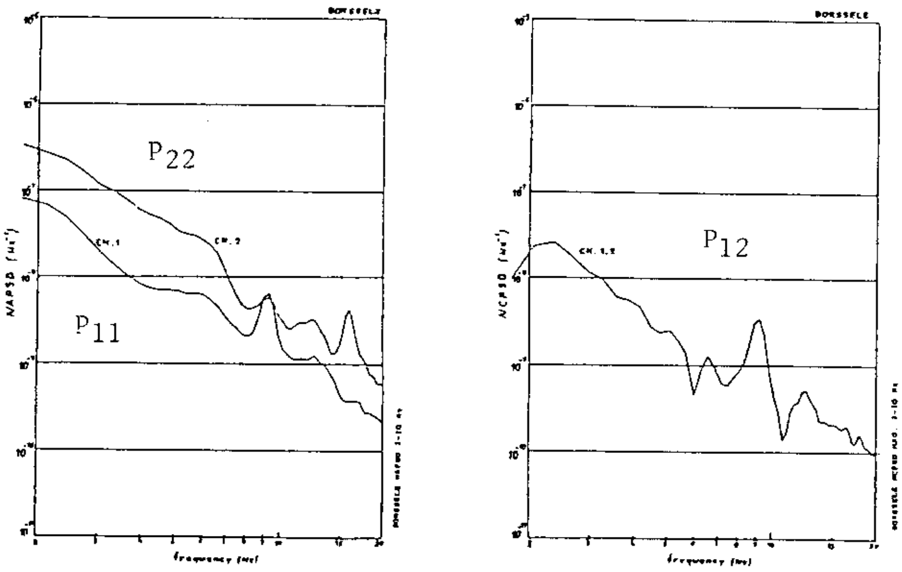
BORSSELE CROSS CORRELATION : IN 12 / LOG

Fig.41 Functions computed by I

Borssele reactor noise

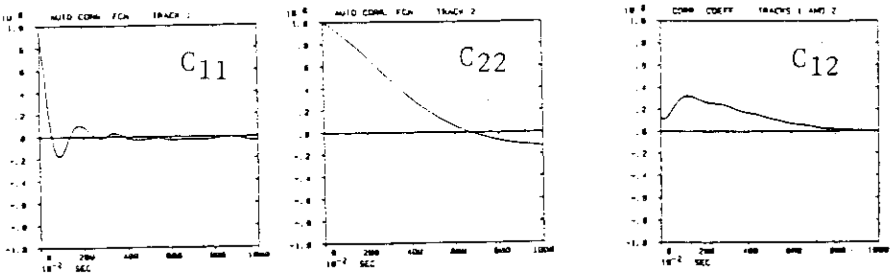


Artificial noise

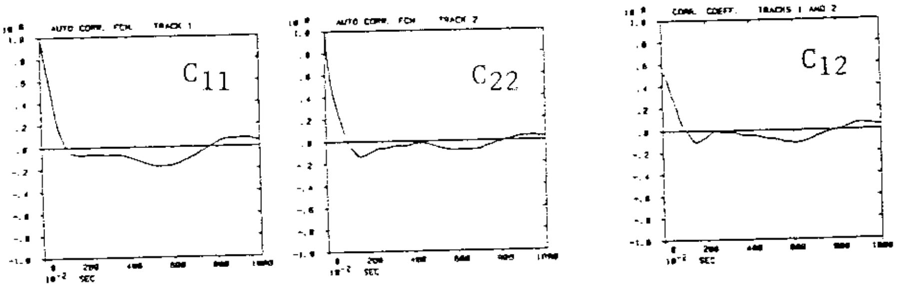


Borssele reactor noise

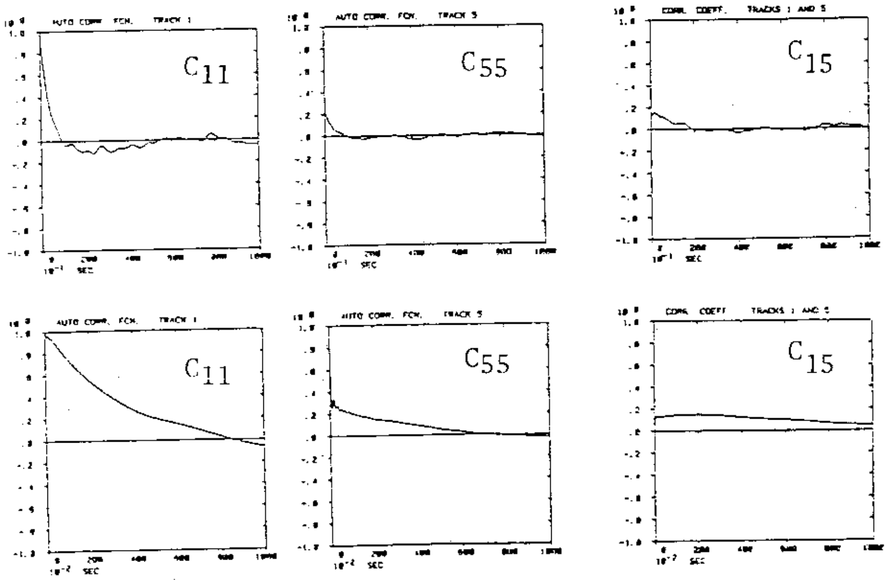
Fig.42 Functions computed by L



Artificial noise

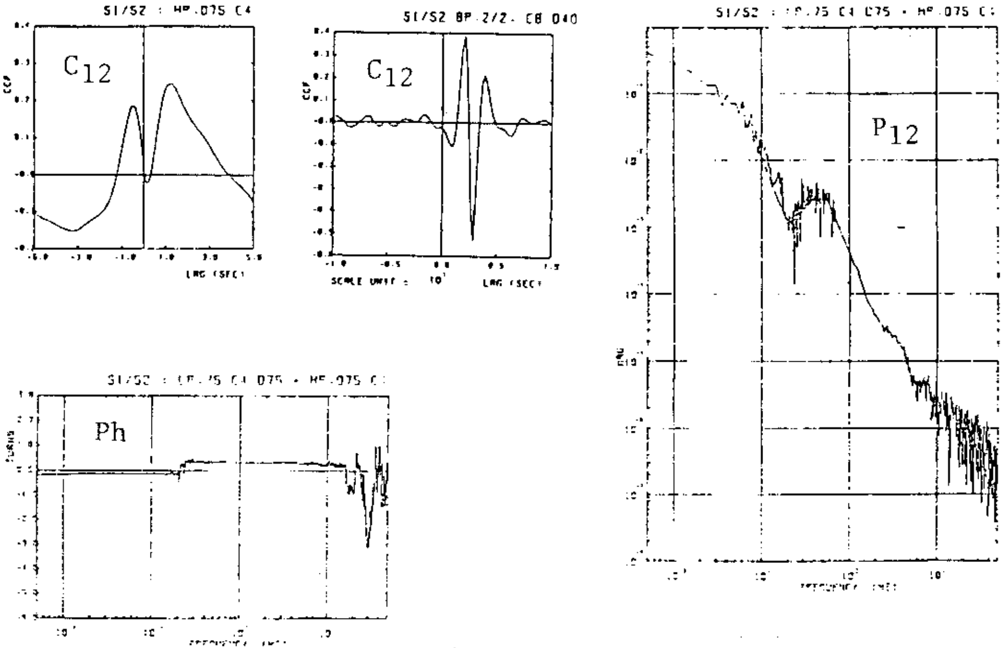


Borssele reactor noise

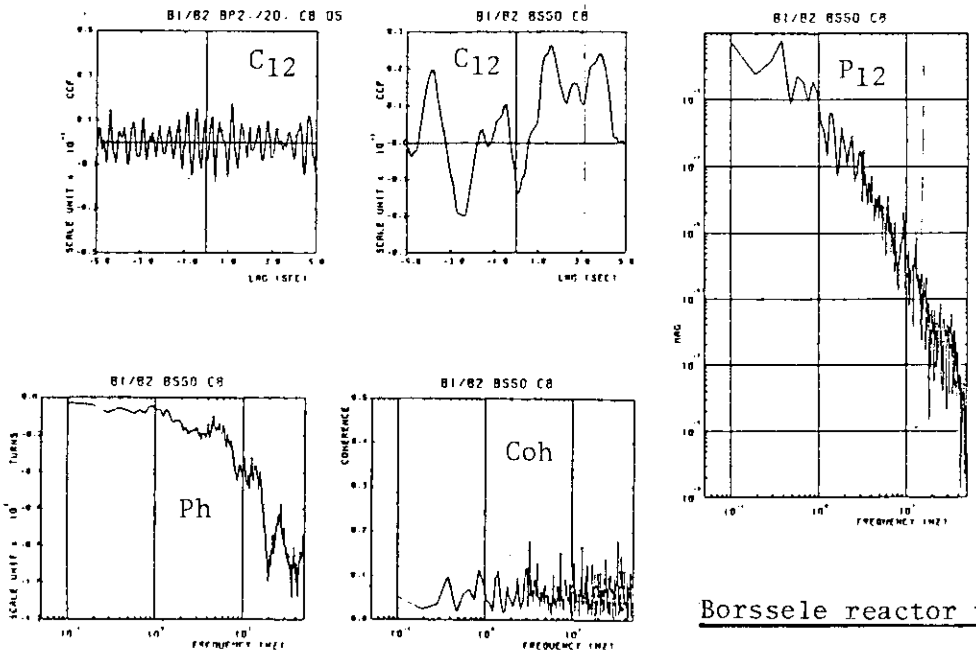


Phenix reactor noise

Fig.43 Functions computed by N



Artificial noise



Borssele reactor noise

Fig.44 Functions computed by W

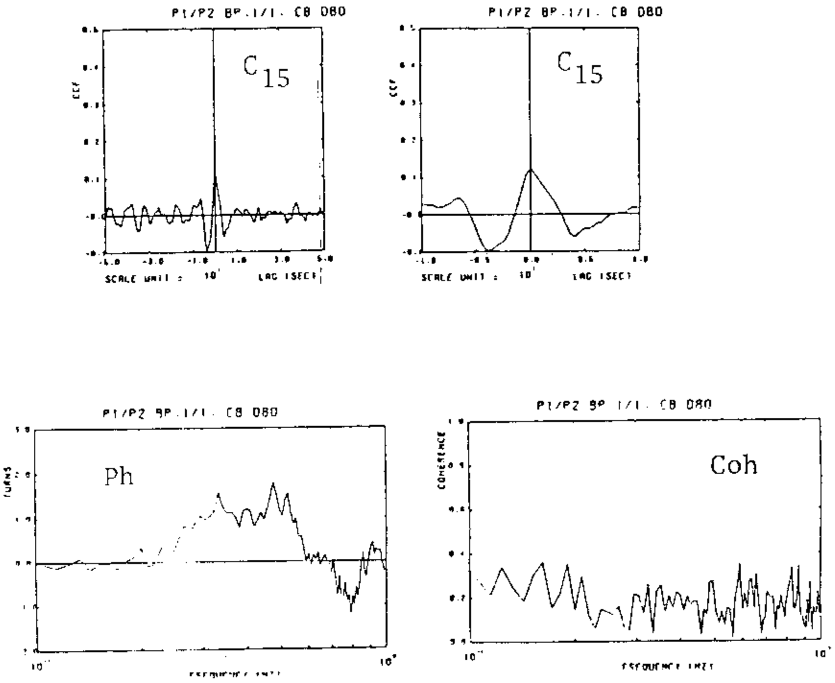


Fig.44 Functions computed by W (continued)

Phenix reactor noise

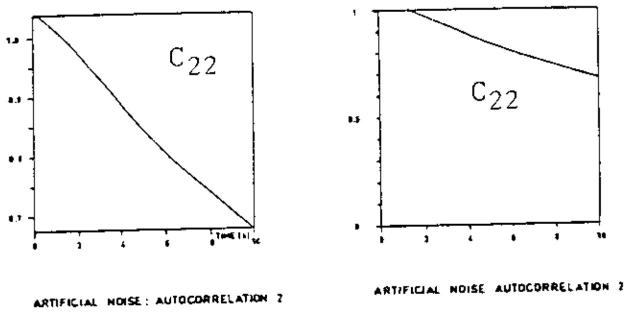


Fig.45 Functions computed by R

Artificial noise

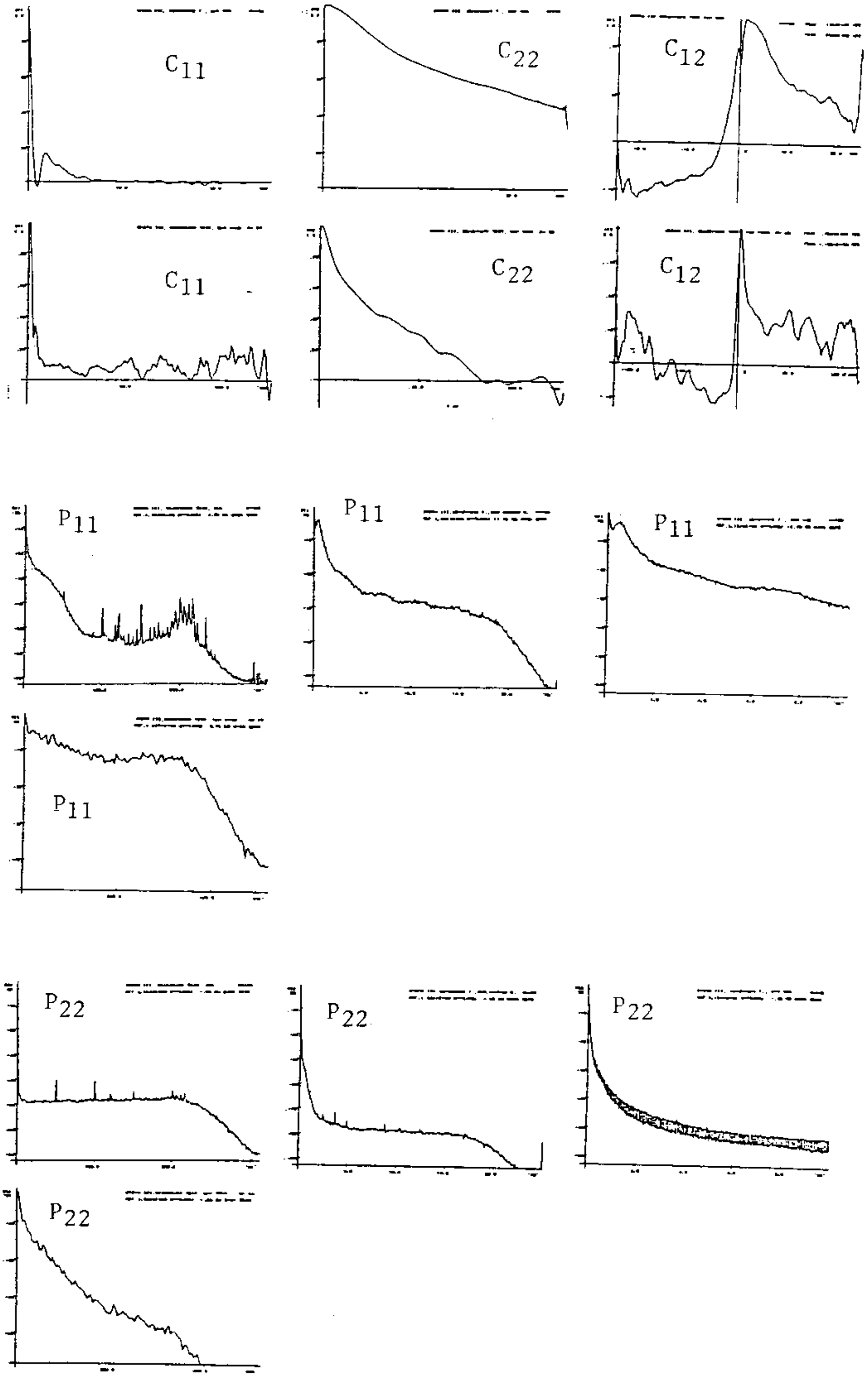


Fig.46 Functions computed by X

<u>Artificial noise</u>

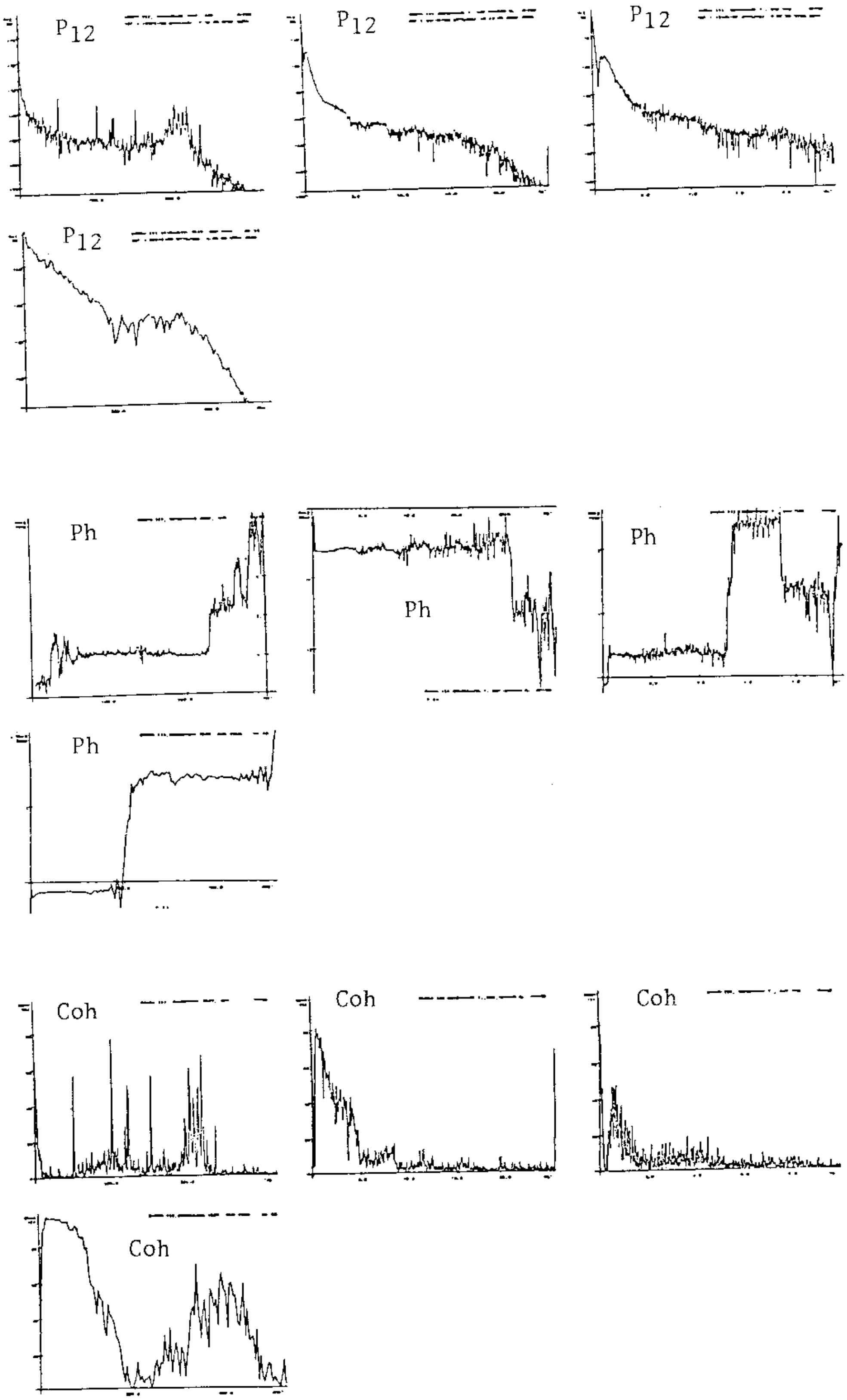


Fig.46 Functions computed by X (continued)
Artificial noise

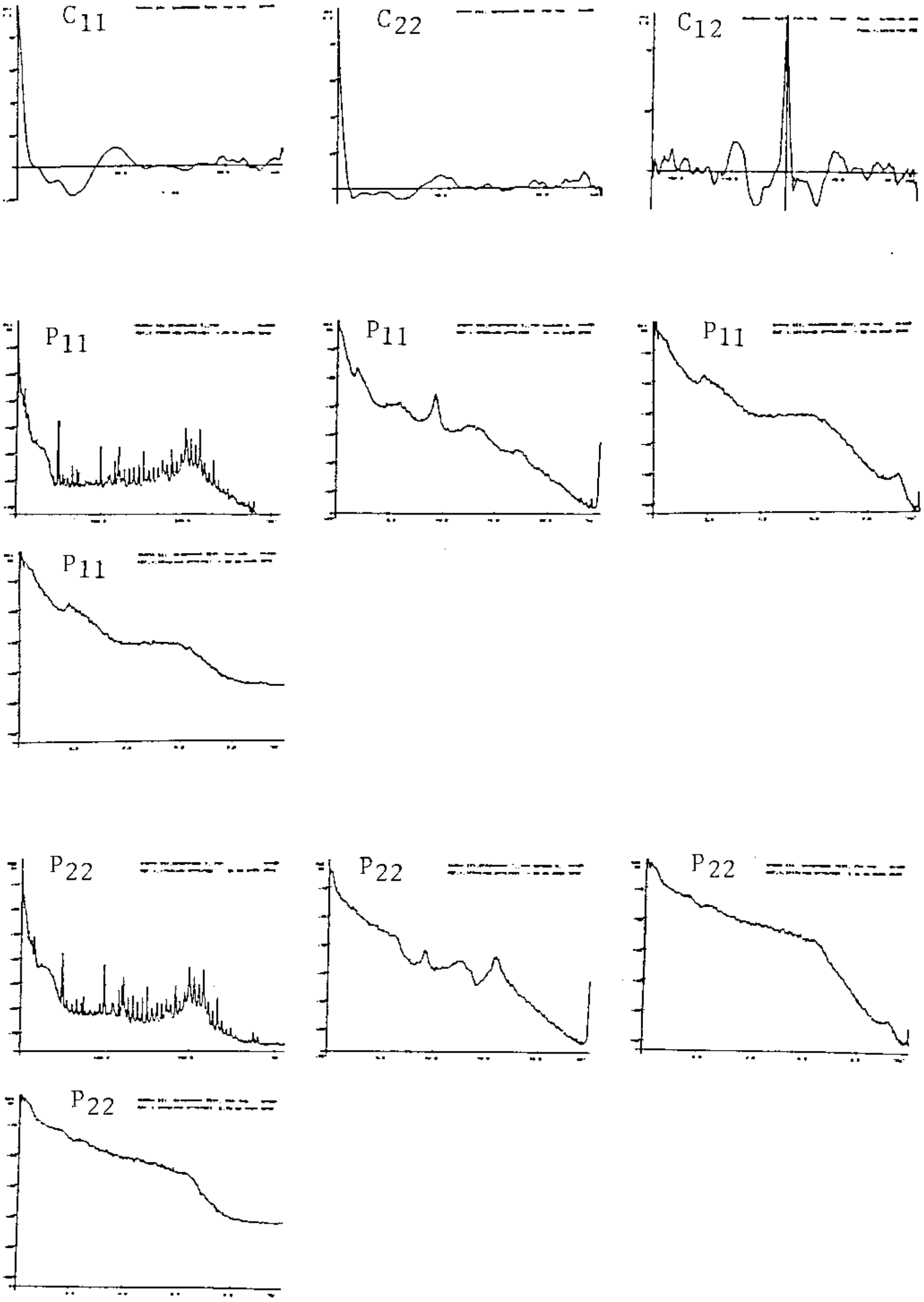


Fig.46 Functions computed by X (continued)

Borssele reactor noise

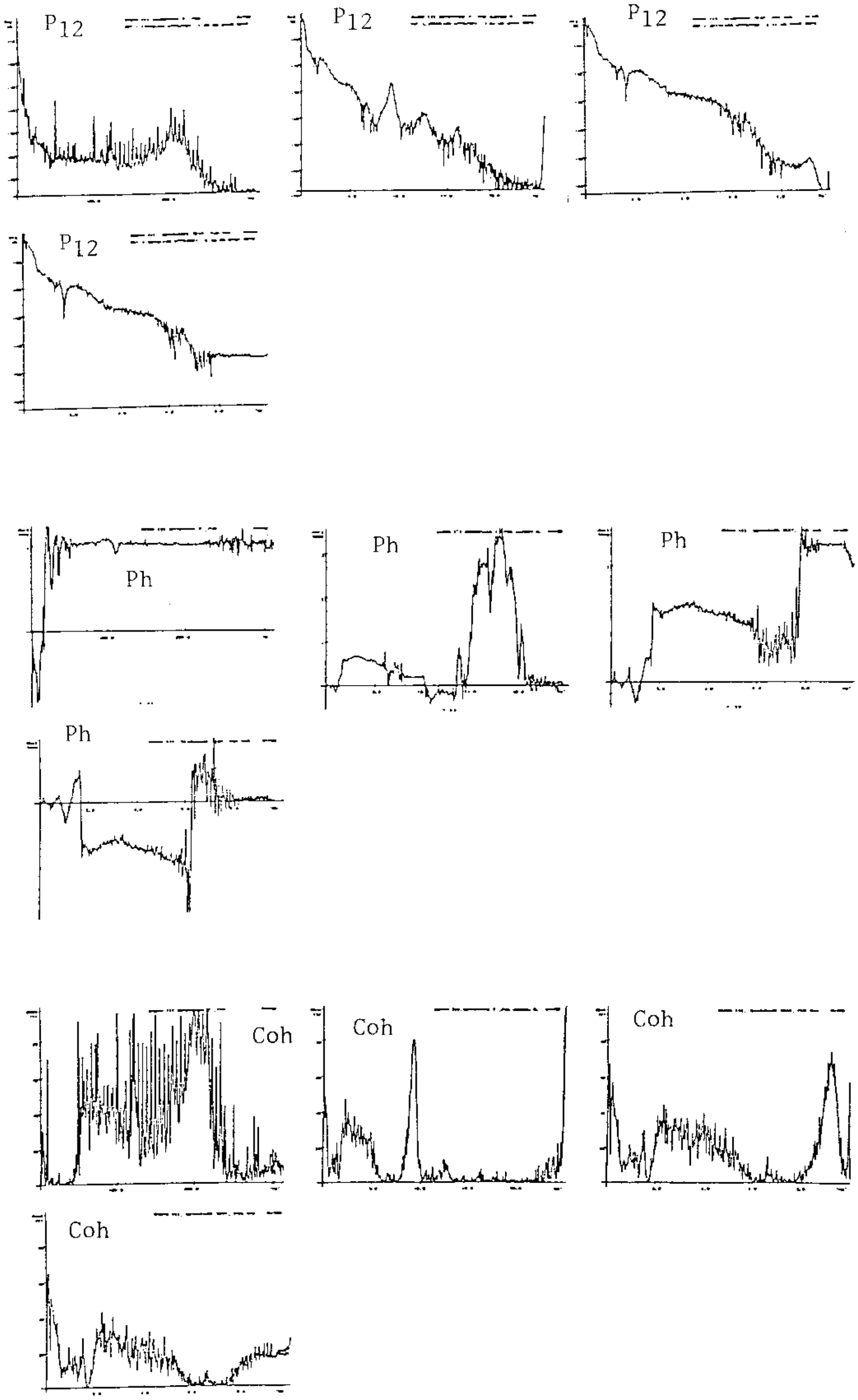


Fig.46 Functions computed by X (continued)

Borssele reactor noise

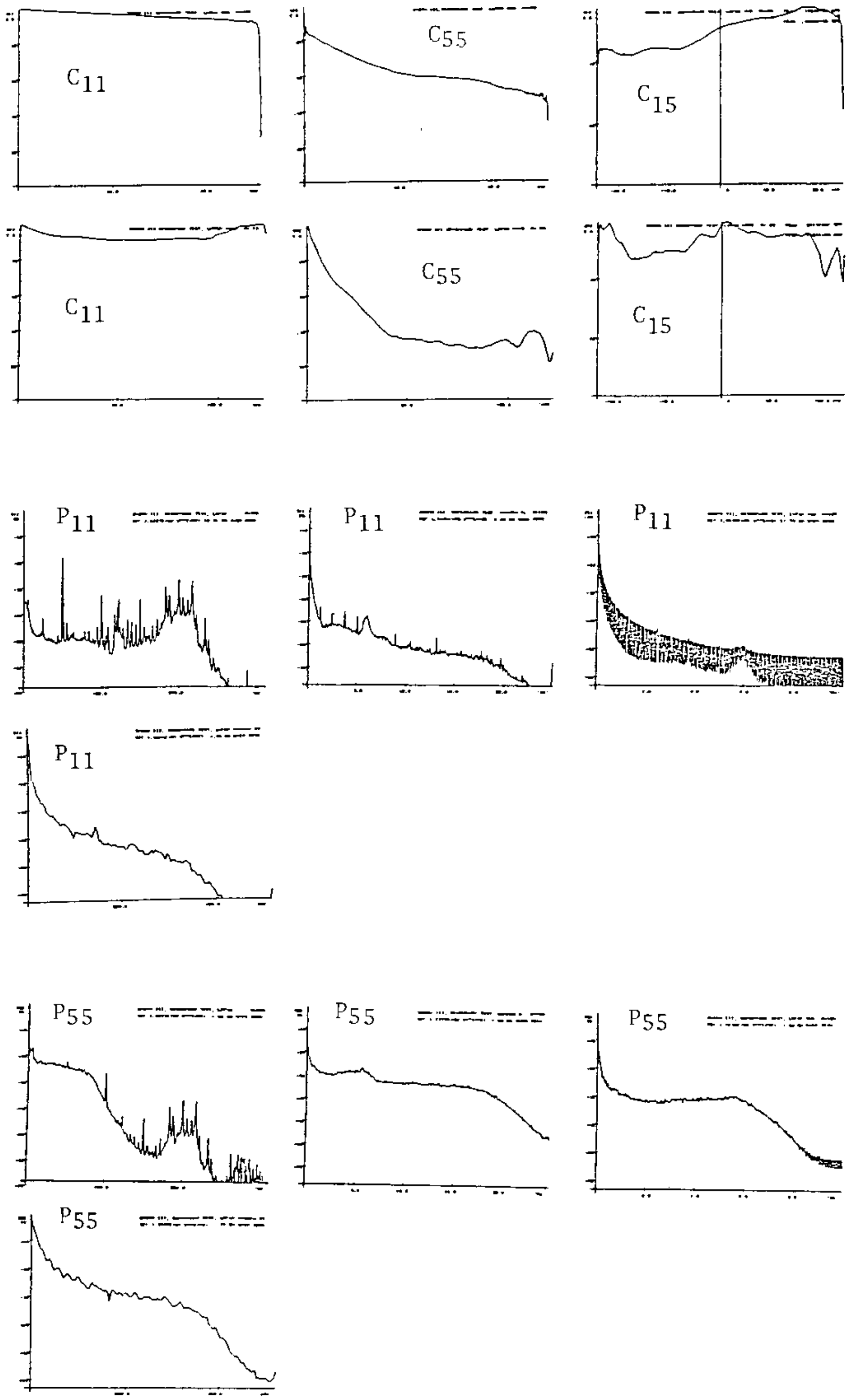


Fig.46 Functions computed by X (continued)

Phenix reactor noise

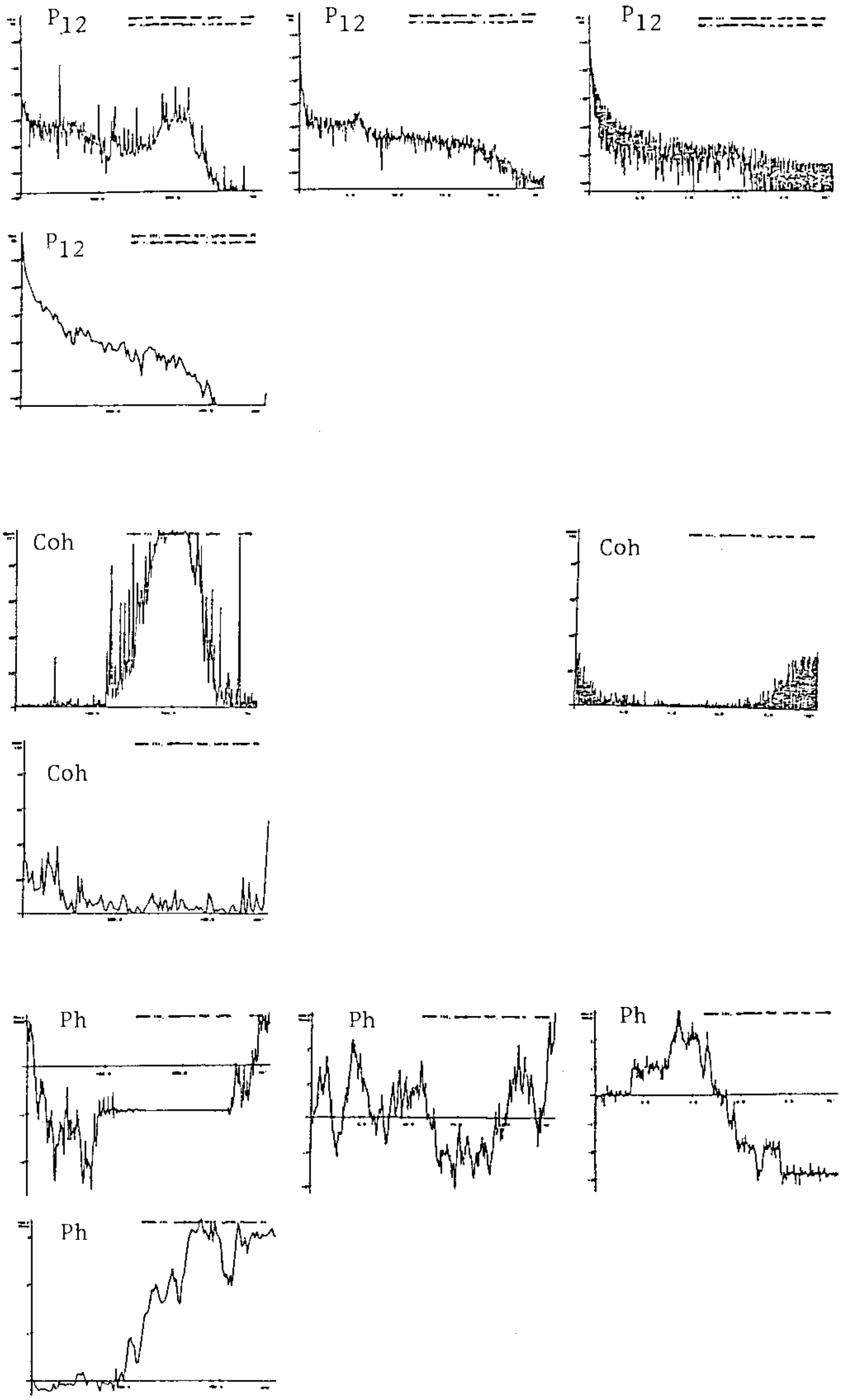


Fig.46 Functions computed by X (continued)
Phenix reactor noise

Renewed analysis of SMORN-III benchmark data

by the contributor Ω

As our APSD of channel 2 from Borssele reactor noise obtained from FFT-analysis data differed from APSDs obtained by a majority of the investigators, we have performed new analyses where we introduced changes in procedure and equipment.

We found that the following changes did not alter the APSDs significantly:

- Use of another computer with another sampling equipment.
- Use of another sampling channel in the original equipment.
- Doubling the sampling frequency.
- Use of another computer program.
- Use of another analog data tape.

We also made a test of our tape recorder by analysing square wave signals directly and via recording and playback. We did not find any significant difference between the results, and thus the tape recorder was not found to influence the signal negatively.

The following change did, however, imply a substantial improvement:

- Increase of the sampling time for each block from 2 to 6 seconds. This was accomplished by doubling the number of data per block and by decreasing sampling frequency. The improvement is shown in Figure 1.

An additional improvement was obtained by:

- Introduction of a high pass filter with a break frequency of 5 Hz at the tape recorder output. Because of the filter, the signal amplification could be increased by a factor of 4 without overloading the AD converter. After this second improvement our APSD agrees, within acceptable limits, with the correct result. The result is shown in Figure 1.

The cause of the deviation was thus a combination of insufficient resolution in the AD converter and too short sampling time for each block. Both these causes were dominant in this case because the interesting part of the APSD contained sharp resonances with low energy, and the dominant part of the energy was in another part of the spectrum.

Figure 1. Normalized auto power spectral density (NAPSD) of Borssele ex-core detector signal (ch. 2)